When do lower upstream prices increase downstream employment? Examining the mechanics of value chain linkages

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1. Introduction

The recently published National Industrial Policy Framework of the South African Department of Trade and Industry outlines the policy proposals for a more interventionist development strategy.

Among other issues, the NIPF investigates the possibility to achieve a labour-absorbing development trajectory through downstream beneficiation of South Africa's natural resources.

"South Africa has an abundance of mineral and plant resources and related comparative advantages such as relatively cheap electricity. The promotion of beneficiation of raw materials in downstream sectors is a logical progression to complete various value chains in the South African economy. These include long-established sectors such as metals fabrication; machinery and equipment; chemicals and plastics, and paper and pulp; as well as emerging sectors such as oil and gas and jewellery. The promotion of beneficiation will not only result in increased value-added of our mineral resources but also create significant employment opportunities since downstream industries have relatively high labour intensity. Obstacles to downstream beneficiation include the pricing of raw materials … interventions to unlock the potential of these sectors include: a regulatory framework for more internationally competitive raw material pricing inputs" (DTI IP draft, 2006, p.31).

The dti I has also stated that it needs to ensure success of the specific methods it chooses to achieve its goals. "The design and implementation of government regulations should take into account both the intended and unintended requirements and costs it may impose on the private sector, that is, government regulation must be as efficient and effective as possible with respect to both small and medium firms" (NIPF, 2007: 31).

As the Department of Trade and Industry identifies, part of the principles and best practice of industrial policy interventions is to acknowledge that "the overall approach to industrial policy is based on the identification of growth and employment constraints operating at the microeconomic, sectoral, spatial and firm level of the economy, rather than a 'one-size-fits-all' policy template" (NIPF, 2007: 30)

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The dti is likely to aim at achieving its downstream beneficiation policy objectives of higher output and employment by identifying labour-intensive downstream industries and then targeting the related upstream prices. However, under what conditions do lower upstream prices lead to rising production and employment downstream? And if so, what is the mechanism through which this takes effect, and what is the degree of transmission? These crucial questions need deeper and more thorough examination.

Thus far, the analysis of the links between different levels of beneficiation in manufacturing has been framed in value chain theory (Gereffi and Korzeniewicz, 1994; Kaplinsky, 2000; Morris and Kaplinky, 2001). The effects of upstream prices on the performance of downstream industries in a number of South African value chains has been analysed using this framework (e.g. Roberts and Zalk, 2004; Dobreva, 2006; Hawthorne and Das Nair, 2006). These studies have painted a more complete picture about the linkages between sectors and shed light on the systemic competitiveness patterns within certain value chains.

However, value chain analysis in its current form is static and based on a set of implicit assumptions, which have not been fully exposed and explored. Only when firm and market dynamics of the various links are taken into consideration, it is possible to identify the extent to which upstream price changes lead to significant changes of downstream production and employment. Hence, even though the hypotheses put forward in these studies may be valid, the relative influence of various factors on the outcomes observed is difficult to judge, especially in a dynamic setting. A more concrete theoretical framework and empirical testing on the mechanism and degree of transmission between upstream prices and downstream output and employment are needed. Otherwise, the success of downstream beneficiation policies is uncertain.

We argue that currently industrial policy in South Africa is based on the use of a simple value chain analysis which is unable to measure the impact which interventionist policies will have. We attempt to develop a model, which incorporates various elasticities throughout the value chain, in order to highlight factors, which will determine the effectiveness of the proposed industrial policies. Without considering these factors, the justification for intervention even in cases of identified existing market failures is problematic as the impact of the intervention itself is unknown.

In this paper, we examine the implicit assumptions behind the value-chain transmission mechanism between upstream prices and downstream output and employment. We emphasize the need for a more rigorous theoretical framework that can be used for empirical testing.

The paper is structured as follows. Section 2 summarises the argument for downstream beneficiation that has been presented by industry case studies done so far. Sections 3 and 4 examine the value chain linkages using mathematical models in order to clarify the underlying implicit assumptions behind value-chain linkages and possible approaches to testing the mechanics and the degree of transmission through these linkages. Section 3 examines the link between lower upstream prices and higher downstream output. Section 4 analyses link between higher downstream output and higher employment. Section 5 concludes.

2. The Value Chain argument for downstream beneficiation

2.1 The Value Chain Argument

The dti has identified several sectors (including metals fabrication; machinery and equipment; chemicals and plastics; and paper and pulp; oil and gas and jewellery), which it considers to have significant potential in terms of downstream output and employment (NIPF, 2007): 36.

As mentioned above, there are various papers looking at the relationship between upstream prices and downstream beneficiation for selected South African industry sectors. To illustrate the argument for downstream beneficiation in such papers, we will look at an analysis of the plastics industry (Dobreva, 2006).

The production of polymers, which are the main material inputs to the production of plastics, is capital-intensive and characterized by economies of scale. The capital-labour ratio for the basic chemicals sector (a broader grouping than polymer producers) was R7.04m per employee in 2002 (Quantec).

Hence the upstream industry displays a significant degree of concentration, with one or two firms that manufacture the main types of polymers. There are four polymer producers in South Africa. The largest by far is Sasol Polymers, a division of Sasol Chemicals, followed by Dow Chemicals, a local subsidiary of the multinational Dow. Sasol Polymers is the largest manufacturer of polypropylene (PP) and is the sole producer of low-density polyethylene (LDPE), linear low-density polyethylene (LLDPE) and polyvinyl chloride (PVC) in South Africa. It operates plants in Sasolburg and Secunda. It also has partial ownership of two plants in Malaysia. Dow Chemicals manufactures polypropylene and high-density polyethylene (HDPE). The two smaller producers are SANS (a subsidiary of AECI) and Hosaf (originally Hoechst SA), each making bottle and fibre grades of Polyethylene Terephthalate (PET).

In contrast, the downstream industry is relatively labour-intensive: the capital-labour ratio for plastics was R33000 per employee in 2002 (Quantec). The industry also displays a lower degree of concentration. The Plastics Federation (Plasfed) reports that there are about 800 firms in South Africa, most of them small or medium-sized.

Labour-abundant South Africa is a net exporter of some unbeneficiated and capital-intensive material inputs into the production of plastic goods. At the same time, there is a considerable trade deficit in semi-finished plastics and a small and falling trade deficit in finished goods. Furthermore, certain downstream sectors, which use imported materials, have expanded into export markets and continue to grow rapidly. This pattern of competitiveness seems to imply that there is little benefit to downstream plastics producers of having a local source of supply of inputs, as those inputs are priced at import-parity.

The downstream beneficiation argument revolves around the fact that polymers constitute about 50% of input costs and 30% of the total output value of plastic goods (Table 1). In addition, the labour-intensive production technique is reflected in the fact that labour costs constitute 30% of input costs and 90% of total value added, whereas the corresponding figures for the production of polymers producers are 9.5% and 35% (Statistics South Africa, Final supply and use tables, 2000; note that polymers are referred to as primary plastics in Statistics SA data).

Table 1. Plastic products - sources of inputs and value added, 2000

Product grouping	R millions
Agriculture & mining	100
Textile products	80
Wood & paper products	237
Petroleum & basic chemicals	465
Primary plastics	3 362
Other chemicals	145
Plastic products	1095
Metal prods & mach	240
Other manufacturing	253
Electricity & water	28
Transport, communication, finance & other services	597
Total inputs at purchasers' prices	***6 611***
Total gross value added (GDP)	***4 479***
Compensation of employees	4 014
Taxes less subsidies	(18)
Gross operating surplus / mixed income	456
Total output at basic prices	***11 090***

Source: Statistics South Africa, Final supply and use tables, 2000

The next step in the above argument would be to suggest that if the prices of upstream inputs were lowered, this would allow for downstream firms to reduce their costs, increase their competitiveness which should assist the producers of more beneficiated goods to expand output, employment and increase their access to export markets.

2.2 Limitations of the Value Chain Argument

There are a number of implicit assumptions that this kind of a downstream beneficiation argument is based on.

- The argument is of a static nature, as the input-output ratios apply to a particular point in time and to a specific level of output and employment. The methodology behind Stats SA's Supply and Use Tables involves fixed input proportions.

- In turn, a fixed proportions technology implies no substitutability between the factors of production.

- Complete price transmission from lower upstream to lower downstream prices is assumed. This needs further examination. There are numerous international studies that estimate the degree of price transmission along agricultural value chains, but there are no estimates that we are aware of for manufacturing value chains, internationally or in South Africa.

- The argument requires a linear output expansion path. The downstream industry is assumed to be perfectly competitive in all its product categories and produce most efficiently on a small or medium scale over a large range of output. In other words, input ratios are independent of the level of output and of production technology.

- The input prices are assumed to be fixed, regardless of changes at various levels in the value chain.

- Competition in international markets, in which the downstream industry is participates (or desires to participate), is assumed to be on the basis of price or cost of production. Hence, lower input prices, which are transmitted completely to lower downstream prices, then translate into increased competitiveness and export growth.

It can be argued that the use of the value chain approach to inform industrial policy is helpful in identifying potential industries which exhibit exploitable characteristics for the objectives of the dti. Nevertheless, the current use of the value chain approach is limited to identifying a static picture of the relationships of the various links in the value chain. It cannot identify how firms and industries respond to changes in the value chain. It ignores the dynamic mechanisms that inform the responses by firms and entire industries to changes.

According to the NIPF, the dti aims to diversify the South African economy into "new more labour-absorbing and value-adding tradable goods and services. Both the international evidence and our own economic history indicate that this process often does not happen automatically and therefore *requires purposive effort*. *High impact sector strategies that are well designed and implemented are crucial* to place the economy on a higher growth and more developmental industrialisation path" (NIPF, 2007: 33, Italics added)

The following section is an attempt to explore the limitation of the value chain approach. We use mathematical models to examine the value chain linkages and various elasticities. This should allow us to investigate or at least highlight factors which will determine the effectiveness of the proposed policy interventions. Without taking into account the degree to which firms and industries respond to various policy interventions it is impossible to identify and implement an effective industrial policy framework.

3. The link between upstream and downstream prices

3.1 Pass-through of price changes through the value chain

Empirical studies on the degree of transmission between a change in upstream (input) price and the change in price of a more beneficiated good are relatively common in agricultural economics (Sheldon, 2006; McCorriston *et al,* 2001). In turn, the theoretical and empirical models of incomplete price transmission in agricultural products are based on studies from the realm of public economics about the spread of effects of tax changes (Stern, 1987; Colangelo and Galmarini, 2001).

We use Sheldon's (2006) discussion regarding the conditions, which determine the degree of pass-through from prices of raw agricultural inputs to prices of intermediate and final goods. The model assumes that the sector, producing the raw commodity is perfectly competitive, but that the industries, in which the intermediate and final products are manufactured, exhibit some degree of imperfect competition.

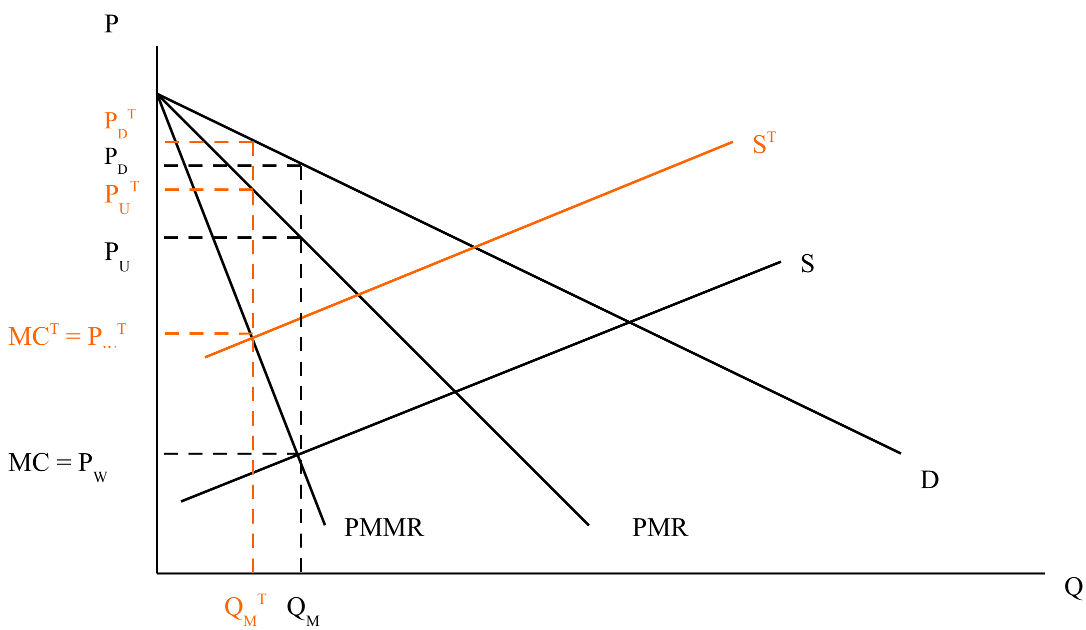
The model makes the strong simplifying assumption that technology at each level of processing is characterised by fixed proportions and hence constant returns to scale. More specifically, one unit of the primary commodity is transformed into one unit of the intermediate good and one unit of the final good. In other words, the primary commodity is assumed to be the only input into the production of the intermediate good and, in turn, the intermediate good is the only input into the manufacturing of the final good. Of course, this assumption is far from realistic and it amplifies the degree of price transmission under any market conditions (namely, any price elasticity of demand and market structure at each level of processing).

The model assumes that a primary agricultural commodity is beneficiated in an upstream and a downstream sector before being sold to the final consumer. The primary good is assumed to be produced and sold in a perfectly competitive market (often the world market). The upstream and downstream industries are implicitly assumed to operate in the local market and so their market structure matters in that context.

The essence of the model can be illustrated as follows. In Figure 1, the demand for the final good is denoted by D; hence PMR is the perceived marginal revenue of the downstream imperfectly competitive producer. The upstream imperfectly competitive producer sees PMR as its demand curve (because demand from the upstream industry is a derived demand) and thus PMMR is in turn its perceived marginal revenue curve.

Sheldon discusses the effects of imposing a tariff on the primary commodity on the prices of the upstream and the final good. If S is the world supply of the primary commodity, and S^T is the tariff-laden supply curve, then the transmission of this to changes of the prices of the upstream and downstream goods depends on the industry structure of each level in the value chain (Figure 1).

Figure 1
The transmission of upstream to downstream prices when a tariff is introduced (Sheldon, 2006)



Graphically, the more concentrated the downstream industry is, the steeper (i.e. more inelastic) is the demand curve for the final good D. The per-unit profit at each level of beneficiation can be represented by the price differential at each level of the value chain from the previous level of processing. That is, the profit per unit of the upstream industry is $(P_U - P_W)$ and the profit per unit of the downstream industry is $(P_D - P_U)$. The more concentrated the upstream and downstream industry, the steeper is the demand curve D and the smaller is the pass-through – the largest proportion of the rents (i.e. rise in per-unit profit), associated with the tariff imposed on the primary commodity, is appropriated by the upstream industry. That is, $(P_U^T - P_U) > (P_D^T - P_D)$.

Sheldon then uses a game theoretic approach, and more specifically a generalised Cournot model, to capture different types of market structure in the upstream and downstream processing industries.

The game has three stages. At the first stage, the government commits to a specific tariff for the unprocessed commodity. At the second stage, the upstream firms take the tariff-ridden commodity price as given and choose the level of output for their intermediate processed good. At the third stage, the downstream firms take the price of the intermediate processed good as given and choose the level of output of the final good to be sold to the final consumer. The game is solved by backwards induction.

Assuming there are n downstream firms, let x_i be the output of a representative firm *i*.

Let the general cost function of a representative downstream firm would be:

$$c_i^d = k^d + \beta p_1^u x_i + (1 - \beta) p_2^u x_i \qquad \textbf{(1)}$$

where k^d equals downstream fixed costs and $p_1^u x_i$ and $p_2^u x_i$ refer to the cost of purchasing the intermediate (upstream) goods 1 and 2 respectively, and β and (1-β) refer to the shares of the upstream goods 1 and 2 in the total cost of production downstream.

For simplicity of our argument, we assume that $x_j^u = x_i^d = x_i$, i.e. that technology is such that one unit of the intermediate (upstream) good is transformed into one unit of the final good and that β is 1, i.e. that the cost of the upstream good 1 is the only variable cost for producing the downstream good. Hence the cost function becomes:

$$c_i^d = k^d + p^u x_i \qquad \textbf{(2)}$$

The inverse demand function downstream is given by:

$$p^d = \phi(X), \text{ where } X = \sum_{i=1}^{n} x_i \qquad \textbf{(3)}$$

Each firm *i* conjectures that the reaction of other firms to its own level of output is given by:

$$\alpha^d = \frac{\partial (X - x_i)}{\partial x_i}\left(\frac{X - x_i}{x_i}\right) \qquad \textbf{(4)}$$

Where:

α^d is the coefficient of conjectural variation, or the elasticity of all other downstream firms' output to the output of firm *i* , where $0 \leq \alpha_i \leq 1$

x_i is the output of firm *i*

X is the total downstream industry output, i.e. $X = \sum_{i=1}^{n} x_i$

A necessary condition for profit-maximisation is that each downstream firm *i* chooses its output so that marginal revenue equals marginal cost, where marginal revenue is its perceived marginal revenue curve.

$$p^d\left\{1-\frac{\alpha^d+(1-\alpha^d)s_i^d}{\eta^d}\right\}=p^u \qquad \textbf{(5)}$$

Where

s_i^d is the market share of the i^{th} downstream firm

η^d is the price elasticity of demand for the final good.

Assuming that all downstream firms produce a homogeneous product with identical technology, and adding and dividing by the number of firms, *n*:

$$\frac{1}{n}\sum_{i=1}^{n} p^d\left\{1-\frac{\alpha^d+(1-\alpha^d)s_i^d}{\eta^d}\right\}=\frac{1}{n}\sum_{i=1}^{n} p^u \qquad \textbf{(6)}$$

Simplifying, we get:

$$p^d\left(1-\frac{\alpha^d+(1-\alpha^d)/n}{\eta^d}\right)=p^u \qquad \textbf{(7)}$$

Let $\gamma^d=\dfrac{\alpha^d+(1-\alpha^d)}{n}$, where $0\le\gamma^d\le 1$. **(8)**

Thus, we get:

$$p^d\left(1-\frac{\gamma^d}{\eta^d}\right)=p^u \qquad \textbf{(9)}$$

The existence of a solution requires $\gamma^d<\eta^d$.

This is the "generalised Cournot equilibrium" (Stern, 1987). Here, there are two special cases: downstream monopoly, which corresponds to $n = 1$, $\gamma^d=1$; and perfect competition downstream, which is represented by $k^d = 0$ and $\gamma^d=0$. Cournot-Nash requires $\gamma^d=\dfrac{1}{n}$.

At the upstream stage, the output of a representative firm is x_j and each firm has a cost function: $c_j^u=k^u+p^a x_j$, where k^u represents upstream fixed costs and $p^a x_j$ is the cost of purchasing the primary commodity. We assume that technology requires

$x_j^a = x_j^u = x_j = x_i$, i.e. it is characterised by one-to-one fixed proportions and constant returns to scale.

We use the downstream demand function to substitute for p^d, i.e. $p^d = \phi(X)$, hence:

$$p^u = \theta(X|\eta^d, \gamma^d) \qquad \textbf{(10)}$$

A necessary condition for profit-maximisation is that each upstream firm *j* chooses its output so that marginal revenue equals marginal cost, where marginal revenue is its perceived marginal revenue curve.

$$p^u \left\{ 1 - \frac{\alpha^u + (1-\alpha^u) s_j^u}{\eta^u} \right\} = p^a \qquad \textbf{(11)}$$

Where

s_j^u is the market share of the i^{th} downstream firm

η^u is the price elasticity of demand for the final good.

Assuming that all upstream firms produce a homogeneous product with identical technology, and adding and dividing by the number of firms, *m*, this gives:

$$p^u \left(1 - \frac{\gamma^u}{\eta^u} \right) = p^a \qquad \textbf{(12)}$$

Where

p^a is the price of the primary commodity, and

$$\gamma^u = \frac{\alpha^u + (1-\alpha^u)}{m}\text{, where } 0 \le \gamma^u \le 1. \qquad \textbf{(13)}$$

The existence of a solution requires $\gamma^u < \eta^u$. The special case of upstream monopoly is represented by $m = 1$ and $\gamma^u = 1$, while perfect competition upstream corresponds to $k^u = 0$ and $\gamma^u = 0$. Cournot-Nash requires $\gamma^u = \frac{1}{m}$.

This "generalised Cournot equilibrium" gives the following relationship between the price of the upstream good and the price of the primary commodity:

$$p^u = p^a\left(\frac{\eta^u}{\eta^u - \gamma^u}\right), \qquad \textbf{(14)}$$

Where $\frac{\eta^u}{\eta^u - \gamma^u} > 1$, if $\gamma^u < \eta^u$.

Similarly, the relationship between the price of the final (downstream) good and the price of the intermediate (upstream) good is:

$$p^d = p^u\left(\frac{\eta^d}{\eta^d - \gamma^d}\right), \qquad \textbf{(15)}$$

Where $\frac{\eta^d}{\eta^d - \gamma^d} > 1$, if $\gamma^d < \eta^d$.

Hence, the pass-through from a change in the price of the primary good to the price of the final good can be measured by the relationship:

$$p^d = p^a\left(\frac{\eta^u}{\eta^u - \gamma^u}\right)\left(\frac{\eta^d}{\eta^d - \gamma^d}\right) \qquad \textbf{(16)}$$

Therefore, even under the strong assumption of one-to-one fixed proportions in all the input-output relationships along the value chain, the pass-through effect from the price of the primary commodity to the price of the final good depends on several factors. These are the elasticity of final demand, the elasticity of upstream demand, the number of upstream firms (m) and downstream firms (n), as well as the coefficients of conjectural variation upstream (α^u) and downstream (α^d), i.e. the market structure at each level of the value chain (which is represented by γ^u and γ^d).

In order to illustrate the pass-through effects, we examine four special cases next.

(i) <u>Perfect competition in both the upstream and downstream industries</u>

We assume $k^u = 0$, $\gamma^u = 0$, $k^d = 0$ and $\gamma^d = 0$. Under the one-to-one technology at all levels of beneficiation, this ensures perfect pass-through, so that $p^d = p^a$. The result is independent of the elasticities of upstream and downstream demand.

(ii) <u>Monopoly in the upstream industry and perfect competition in the downstream industry</u>

We assume m = 1, $\gamma^u = 1$, $k^d = 0$ and $\gamma^d = 0$. This implies some degree of rent retention in the upstream industry, which is dependent on the elasticity of demand for the intermediate (upstream) good, so that:

$$p^d = p^a\left(\frac{\eta^u}{\eta^u - 1}\right) = p^u \qquad \textbf{(17)}$$

(iii) Perfect competition in the upstream industry and monopoly in the downstream industry

(This is equivalent to a monopsony in the downstream industry.) We assume $k^u = 0$, $\gamma^u = 0$, n = 1 and $\gamma^d = 1$. This implies some level of rent retention in the downstream industry, which is dependent on the elasticity of demand for the final (downstream) good. The downstream industry competes any gains away. Hence:

$$p^d = p^a\left(\frac{\eta^d}{\eta^d - 1}\right) \qquad \textbf{(18)}$$

(iv) Monopoly in both the upstream and downstream industries

We assume m = 1, $\gamma^u = 1$, n = 1 and $\gamma^d = 1$. This implies sharing of rents in the upstream and downstream industries, which is dependent on both elasticities of upstream and downstream demand, so that:

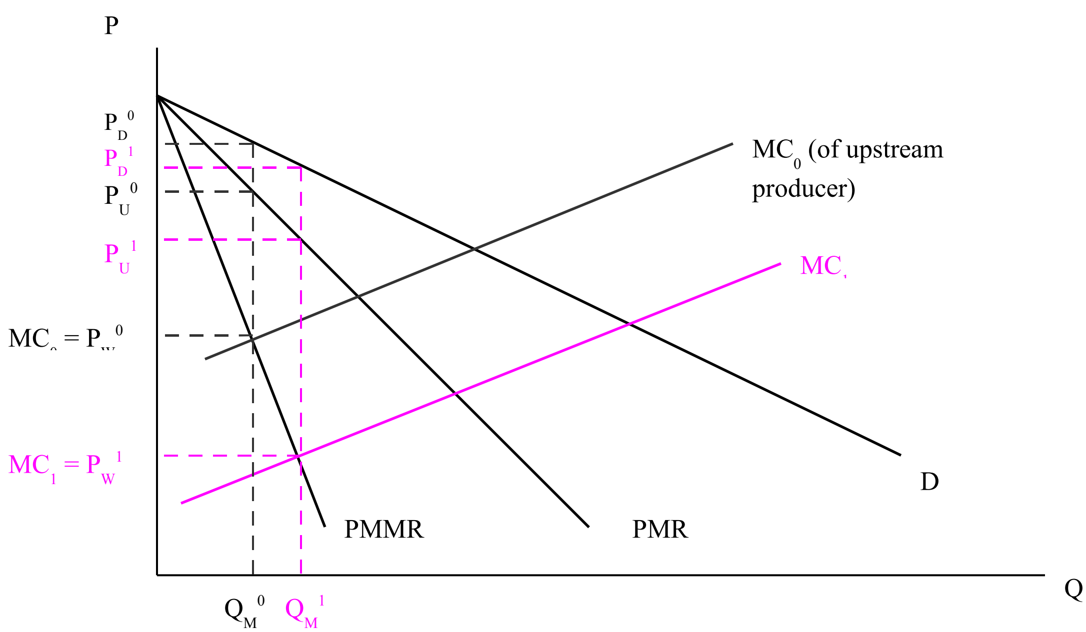
$$p^d = p^a\left(\frac{\eta^u}{\eta^u - 1}\right)\left(\frac{\eta^d}{\eta^d - 1}\right) \qquad \textbf{(19)}$$

In the context of the downstream beneficiation argument presented earlier, this implies that even under the assumption of one-to-one fixed proportions technology, the pass-through effects from lowering upstream prices to downstream prices will depend on the elasticity of intermediate and final demand, as well as the structure of the upstream and downstream industries. The more elastic are intermediate and final demand, the greater the degree of pass-through. The larger is the number of upstream and downstream firms and the closer to unity is the coefficient of conjectural variation (α_i), the better is the transmission of the change in upstream price to downstream price.

If the technology requires more than one input, however, this automatically limits the pass-through effect. For example, in the case of the plastics industry, under conditions that allow for complete pass-though, a 10% decrease in the price of polymers (the upstream good) would lead to a 3% lowering in the price of a downstream plastic product. Clearly, the smaller the proportion of the upstream input into the total cost of downstream production, the more substantial needs to be the fall in price of the upstream good to induce a notable drop in the price and hence a rise on the output of the more beneficiated product. In addition, if the assumption of fixed proportions is also relaxed, this would mean further ambiguity on the effect change in upstream prices on downstream prices.

A simplified version of the downstream beneficiation argument, under the assumption that there is some degree of imperfect competition in both the upstream and downstream industries, is presented graphically in Figure 2. If the upstream price is lowered through, say, a subsidy of the intermediate good or through provision of the primary commodity more cheaply, the marginal cost curve of the upstream manufacturer shifts from MC_0 to MC_1. The upstream price falls from P_U^0 to P_U^1, which represents a smaller change than the drop in marginal cost. The downstream price decreases from P_D^0 to P_D^1. Thus, the resulting benefits (rents) are retained in both the imperfectly competitive upstream and downstream industries.

Figure 2
The transmission of lower upstream prices to downstream prices and output (our adaptation of Sheldon's model)



3.2 The link between changes in upstream prices and downstream output

This link depends on the industry structure at each level of the value chain. Within the model, presented above, using the relationship between the prices of the primary good and the final good in **(19)**, the downstream demand curve can be written as:

$$p^d = \phi(X, p^a, \eta^u, \eta^d, \alpha^u, \alpha^d, m, n) \quad \textbf{(20)}$$

In the simplest case of a linear downstream demand curve, it may be given by:

$$q^d = a - b\left[p^a \left(\frac{\eta^u}{\eta^u - \gamma^u} \right) \left(\frac{\eta^d}{\eta^d - \gamma^d} \right) \right] \quad \textbf{(21)}$$

where a > 0 and b > 0 are constants.

Hence, the elasticity of downstream demand with respect to the price of the primary commodity is given by:

$$\eta_{q^d, p^a} = \frac{\partial q^d}{\partial p^a} \left(\frac{p^a}{q^d} \right) = -b\left[\left(\frac{\eta^d}{\eta^d - \gamma^d} \right) \left(\frac{\eta^u}{\eta^u - \gamma^u} \right) \right] \left(\frac{p^a}{q^d} \right) \quad \textbf{(23)}$$

In the case of a <u>constant (own-price) elasticity</u> of demand for the downstream good, the demand curve could be:

$$q^d = (p^d)^{\eta^d} = \left[p^a \left(\frac{\eta^d}{\eta^d - \gamma^d} \right) \left(\frac{\eta^u}{\eta^u - \gamma^u} \right) \right]^{\eta^d} \quad \textbf{(24)}$$

Hence, the elasticity of downstream demand with respect to the price of the primary commodity in this case is given by:

$$\eta_{q^d, p^a} = \frac{\partial q^d}{\partial p^a} \left(\frac{p^a}{q^d} \right) = \eta^d \quad \textbf{(25)}$$

As we conjectured earlier, the responsiveness of downstream quantity demanded to changes in the price of the primary commodity is dependent on a range of factors: the slope of the final good's demand curve, the elasticities of demand for the intermediate and final products as well as the market structure of the upstream and downstream industries – not only the number of producers, but also the conjectural variation in their output (their responsiveness to changes in other firms' output).

In short, the condition required for a high degree of pass-through from a lowering of the price of a primary or intermediate good to the increase in downstream output include perfect competition and/or very high elasticities of demand at the various stages in the production chain, as well as fixed proportions technology and constant returns to scale, regardless of the level of output. We return to the notion of the possible dependence of input ratios on the level of output in Section 3.3 of the paper.

Further, the determinants of elasticity will influence the long-run effects of price changes. Even in the case where the responsiveness of downstream output to changes in the price of the primary commodity boils down to just the elasticity of demand of the final good, this in turn has several determinants. The nature of competition that downstream producers face (on price/cost versus quality, design and delivery, for example), their ability to access export markets, the nature of the final goods (normal or inferior goods, the latter having less elastic demand), and the time elapsed since the input price change all play a part in determining the size of the increase in output of the final good as a result of lower input costs.

To sum up, when the intermediate good's price drops in conditions of imperfect competition at one or more levels in the value chain, this is likely to result in a redistribution of rents. For instance, in the plastics value chain, if the price of polymers is regulated downwards, and some of the sectors downstream are oligopolistic in nature (as is the case with plastic pipes manufacturing), this will increase the profits of downstream firms at the expense of polymer producers without necessarily bringing about a significant increase in downstream output and hence employment as well.

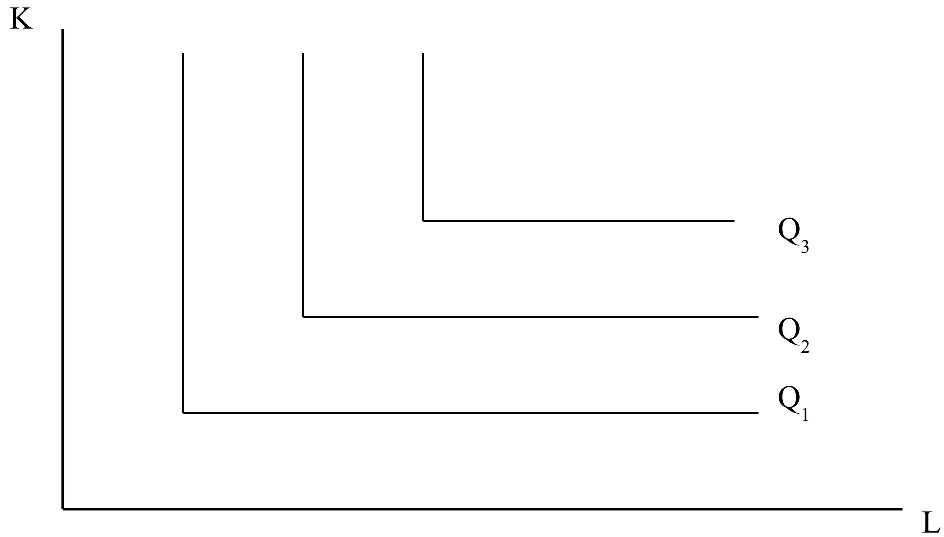
In addition, looking at the broader context, if there is incomplete pass-through from upstream to downstream prices, then the value added in the industry producing the final good rises, and hence the effective rate of protection of the downstream sector increases. This effect may work as a disincentive for producers of more beneficiated goods to improve their competitiveness and increase their access to international markets, provided that the competition they face is on cost and hence price alone.

3.3 The link between changes in downstream output and labour demand

After the analysis of the relationship between the upstream price and downstream output, one has to look at the relationship between changes in downstream output and changes in employment. According to the dti, downstream beneficiation allows for greater employment, particularly of unskilled workers, because downstream production is unskilled labour intensive.

Again, the question is: under what conditions will an increase in downstream production lead to an increase in employment of unskilled workers? The mere fact that current downstream production is labour intensive does not imply that an increase in output is accompanied with a proportionate increase in the demand for labour. The impact of changes in output on labour demand is determined by the output elasticity of labour demand. Simply using output-to-labour ratios to extrapolate the impact of changes in output on labour demand assumes that the production function experiences constant returns to scale and uses inputs in fixed proportions (without the possibility of substitution between capital and labour), i.e. it is the Leontief-type production function used in Statistics South Africa's Supply and Use Tables (Figure 3).

Figure 3. Isoquants for the Leontief Production function



Furthermore, it is not clear that the downstream capital-labour ratio is independent of the level of output and that technical progress is exogenous and neutral with respect to the factors of production. In the case where we assume that the downstream production function is of the constant elasticity of substitution (CES) type, it is homothetic and it follows Hicksian factor-neutral technical progress, the marginal rate of substitution between capital and labour, ω, and the capital-labour ratio, $k = \frac{K}{L}$, have the following relationship:

$$\log k = \log a + \sigma \log \omega \qquad \textbf{(26)}$$

where σ is constant.

Here, the homotheticity assumption ensures that the capital-labour ratio is independent of the level of output and of the neutral type of technical progress, but is determined simply by the marginal rate of substitution or alternatively on the relative factor prices (Sato, 1977).

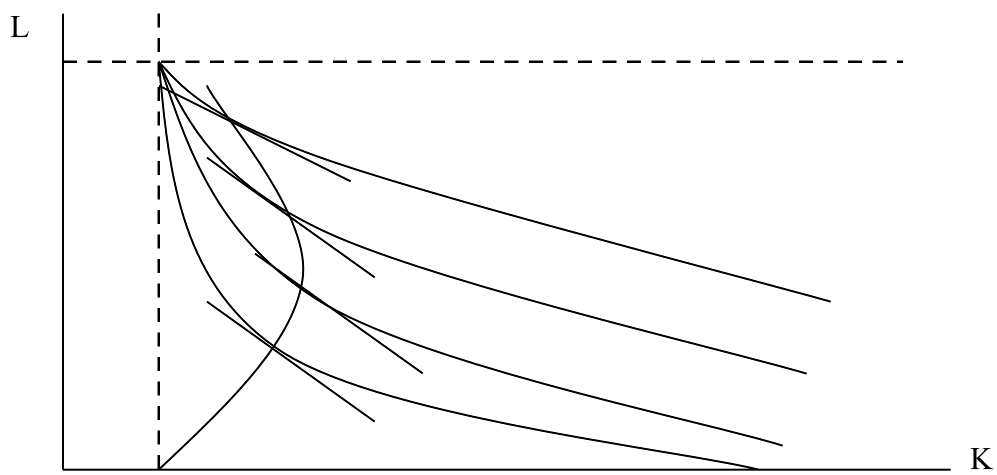
However, the validity of the homotheticity assumption for the production processes employed in the sectors, which have been identified by the dti, has not been tested empirically. Hence, it is possible that the production function is not homothetic and it follows the type of technical progress that is biased towards either capital or labour (often referred to as 'factor-augmenting technical progress'). The non-homothetic type of CES production function can be expressed as:

$$\log k = \log a + \sigma \log \omega + b \log Y + c \log T \quad \textbf{(24)}$$

where Y is the level of output and T(t) is the index of technical progress.

In this case, the level of output and the degree of technical progress will affect the capital-labour ratio explicitly (Sato, 1977). The typical case of an isoquant map of a non-homothetic CES or Cobb-Douglas production function is depicted in Figure 4 below.

Figure 4
The non-homothetic CES or Cobb-Douglas production function (Sato, 1977)



It is important, therefore, to note that if current production levels favour a more labour-intensive production technology, it does not follow automatically that an increase in output does not make a more capital intensive input combinations more attractive. This could be the case in downstream industries which can exploit economies of scale but where the current market size did not allow them to make investments in indivisibles.

The dti identified that "many existing downstream companies in particularly plastic conversion, but also formulation and synthesis *rely upon old technology and practices*, with little focus upon employing global best practice in terms of technology and processes. Within these sub-sectors, *large players produce most of the output*, while the bulk of the number of operations that are relatively small account typically accounts for around one-third of output." (dti, undated online publication, italics added).

Hence, a possible implication of the dti's findings is that with the prospect of manufacturing greater quantities, downstream production could see an increase in investment in capital intensive-production technologies and possibly a consolidation of existing producers. This would make the direction and extent of changes in employment difficult to predict.

4. Conclusion

The aim of this paper is to complement the existing value chain approach by incorporating quantitative arguments, which can shed further light on the mechanics of value chain linkages between prices at different levels of beneficiation, output and employment changes. We examine the implicit assumptions used in constructing value chain arguments, thus highlighting the need for a more explicit theoretical framework.

We argue that the static nature of the value chain arguments made by existing studies, and the assumptions, which need further investigation, mean that the analysis is of limited applicability to policy decisions. By the dti's own criteria, the justification of policy interventions needs to be based on a thorough understanding of the consequences of interventions. The key economic question here remains: will the benefits of pursuing actively interventionist industrial policy, which aims to stimulate downstream beneficiation, exceed the costs of implementation and of changes in incentives? At this point, we simply do not know.

A more elaborate framework for analysing value chains will require further research and it will be invaluable in quantifying the effects of changes in variables, the interactions between variables and the relative importance of these effects. This will allow for empirical studies to be conducted using the little industry-level data available and bring the emphasis once more on the necessity for more such data to be collected.

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