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Colombian Market Liberalisation and Plant Level Production Functions

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Abstract

This paper contributes robust and innovative empirical findings on Colombian within plant and sector productivity outcomes in the final years of Colombian ISI and the initial years of liberalisation. We adapt Levinsohn and Petrin's (2003) advances in estimating production functions to analyse a rich plant level data set which contains both volume and value data.

The principle adaptation provides more stable estimates by subtracting out the non transmitted error term. We also incorporate panel regression techniques so as to clearly identify plant level productivity which otherwise would be swamped by between plant and sector movements, and adjust the GMM moment conditions so as to make full use of our access to the unusually rich plant level dataset.

We find a sharp negative productivity shock across the entire manufacturing sector that coincides with market liberalisation, followed by a slow recovery. This compares dramatically with growing productivity in the ISI period. We have evidence supporting the allocative efficiency gains found in other studies as production shifts within and across sectors. However, these gains do not offset the within plant declines despite growing GDP and increases in capital stock. Finally we find clear evidence against a monotonic relationship between productivity and trade intensity.

Keywords: Colombia, Liberalisation, Import Substitution Industrialisation, Production Function, Total Factor Productivity, Panel Data, Fixed Effects, Time Effects, Endogeneity, Stata

JEL Codes: D24 F13 L60

1. Introduction

1991 saw Colombia energetically throw off decades of protectionism and institute market liberalisation. Colombia's elite embraced the paradigm of the new growth theorists as a high growth alternative to the supposedly defunct policy of Import Substitution Industrialisation (ISI) and the associated disappointing growth of the 1980's.

The policy was meant to promote economic growth by capturing static and dynamic gains. As restrictions on competitive allocations were removed, greater competition and export opportunities would see the reallocation output to more productive plants and activities. In line with the second theorem of welfare economics, such structural change would create welfare and output gains. Over the longer term, productivity gains were expected to outweigh those from any one-off static reallocation of resources. A dynamic process would see companies enter and exit markets based on productivity considerations.

Since the early nineties extensive debate has tended to conclude that the linkages between market regime and productivity are not that simple; particularly as the results of reforms have been mixed. For example, supply response in developing nations may not be as anticipated. The liberalisation view assumes that previously protected enterprises have the capability, time and access to funds, which allow them to modify their production functions through investment and reorganisation in the face of increased competition. Nevertheless, if they foresee demand evaporating (shifting to larger scale, more efficient importers – i.e. losing on Ricardian grounds) investment may not be a logical response. It may be more appropriate to exploit old but cheap technology (only cover variable cost), move to the informal sector or close. These limitations over the whole economy could be reflected in a shortage of managerial know-how, trained labour, investment funds (capped before reforms/ bounded knowledge afterwards), government support; poor government institutions and under developed supply lines.

Through the implementation of methodological innovations in standard growth accounting mechanisms, we estimated plant level productivity responses that should be more stable than previous studies. From these estimates, we analysed if the short and sharp liberalisation process impacted positively on plant productivity or whether other processes were driving changes.

In section 2 we give an overview of the key policy changes during liberalisation. In section 3 we discuss the data and methodological innovations that we have employed and contrast them with other techniques. In section 4 we discuss the choice of proxy variable. In section 5 we take a descriptive look at the economy before we analyse the productivity estimates in section 6.

2. The Colombian Liberalisation: "La Apertura"

The dramatic and comprehensive 1990-reform package during Cesar Gaviria's presidency was not forced upon it by any underlying economic crisis. This lack of economic focus complicated the government's task as they simultaneously introduced market and constitutional reforms. In order to build and maintain support in many constituencies they instituted sophisticated social transfers – which were ultimately inadequate (Berg and Taylor 2000) – and significant reductions in labour costs to check unrest amongst capital owners.

The economic reforms included:

- Trade Liberalisation
- Labour Reform
- Reform of Exchange and Capital Controls
- Financial Reform – including looser FDI regulation

Trade Liberalisation; As can be seen from table 1 and graphs 1, trade liberalisation was rapid and aggressive between 1990 and 1992, with an average 27% point drop in nominal tariffs and 45% point drop in effective rates of protection (Edwards 2001).

Equally as important was the levelling of tariffs, as the standard deviation in tariffs dropped from 9.1 in 1990 to 3.1 in 1992 (Attanasio 2003). This meant that some sectors suffered a greater shock than others. Graphs 1 shows that the unskilled labour intensive sectors (ISIC Sector 32: Textile, Wearing Apparel and Leather Industries; ISIC Sector 33: Manufacture of Wood and Wood Products, Including Furniture; and ISIC Sector 39: Other Manufacturing Industries) suffered the greatest reductions after having been relatively well protected.

Table 1: Reform Period Nominal Import Tariffs & Surcharges (percentages)		
Type of Good	**1990**	**1992**
Consumption Good	53.2%	17.4%
Intermediate Good	35.7	9.9
Capital Good	34.3	10.3
Total	**38.6**	**11.7**
Reform Period Effective Rates of Protection (percentages)		
Consumption Good	109.2%	37.3%
Intermediate Good	60.8	17.6
Capital Good	48.3	15.0
Total	**66.9**	**21.5**

Source: Taken from Edwards (2001) Page 47

Graphs 1; Fall in Nomianl Tariffs

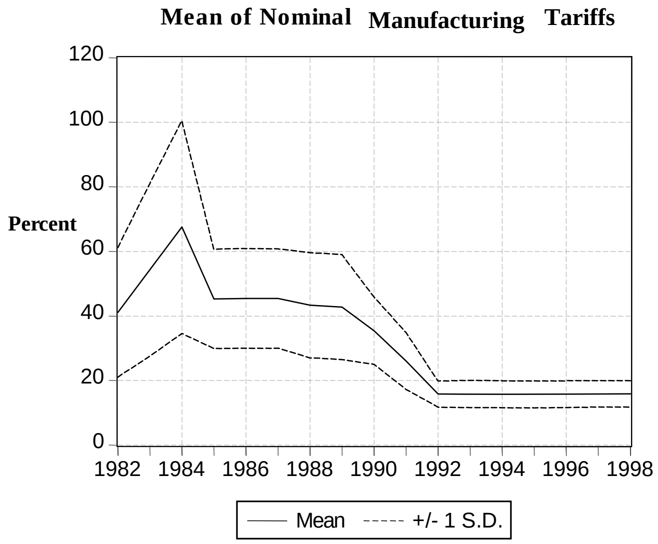
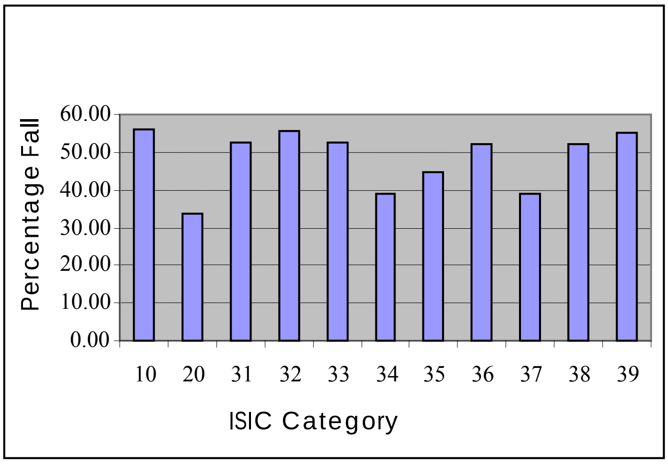


Table 2: Unweighted Fall in Tariffs 1990-1992



Source: Departamento Nacional de Planeación (DANE) figures, Author's Calculations

The graphs 1 also show the movement in tariffs during the 1980s. During the world recession of the early eighties, tariffs increased as did non-tariff protection (through licensing and prohibition of some imports). The aim was to protect industries with higher shares of unskilled workers or those which produced finished goods. From 1985 there was a gradual liberalisation, which mainly focused on streamlining and reducing non tariff barriers.

Labour Reform; These reforms, which mainly came into effect from 1992, were meant to reduce the very high statutory labour costs, compared to the rest of Latin America and make the market more flexible. Statutory employees' benefits became particularly onerous if someone were employed for over 10 years, leading to only 2.5% of employees achieving stability in employment (Edwards 2001). The stated aim of the reforms then became to improve employment stability, but with explicit benefit reductions. In addition, the government increased the transparency and flexibility of temporary contracts. Between 1990 and 1997 the share of temporary employment in total urban employment went from 15.8% to 20% (Ocampo et al 2000). There was also greater legal support for unionisation.

Nevertheless there were very limited gains from these reforms as subsequent reforms in 1993, as well as rising hiring costs and redundancy payments offset any gains.

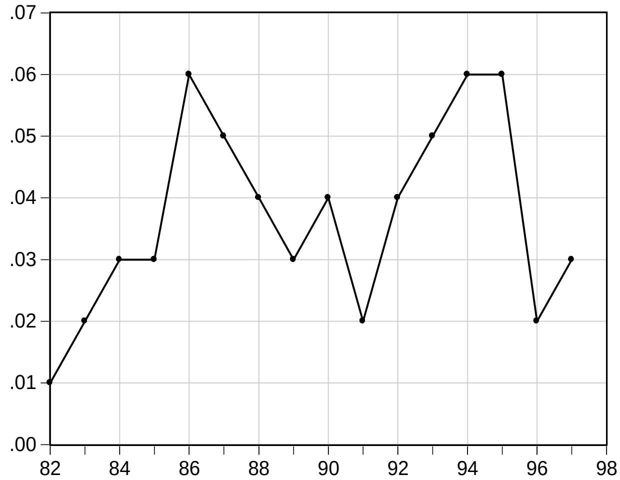
Reform of Exchange and Capital Controls; legislation transferred more power to the central bank; reduced the number of capital controls; and adjusted the long standing crawling peg to a free float. However this last experiment quickly ended on the back of speculation. The central bank reintroduced the crawling peg in September 1993 with a 5% revaluation of the nominal exchange rate. There after the crawl allowed a slight appreciation to accommodate the capital inflow. The continued capital inflows called for a further 7% revaluation at the end of 1994. However, by the end of 1995 the exchange rate was at the top of the band due to political turmoil, but in 1997 it had appreciated to the bottom due to capital inflows. The capital inflows did not consistently find their way into manufacturing but rather government and private spending and the construction and housing bubble; nor did the appreciation help domestic production and exports.

The authorities also reintroduced a number of capital controls in 1994 so as to stabilise the capital flows. These were on debt instruments, corporate equity, property related borrowing and import financing. Foreign Direct Investment was still free from sector restrictions, from the need for prior approval and full repatriation of profits was allowed. Grabel (2004) argues that these capital controls limited the instability that volatile inflows frequently cause developing nations, and indeed the currency bands did hold until they came under severe attack in 1999 (see Mishkin and Savastano (2001)).

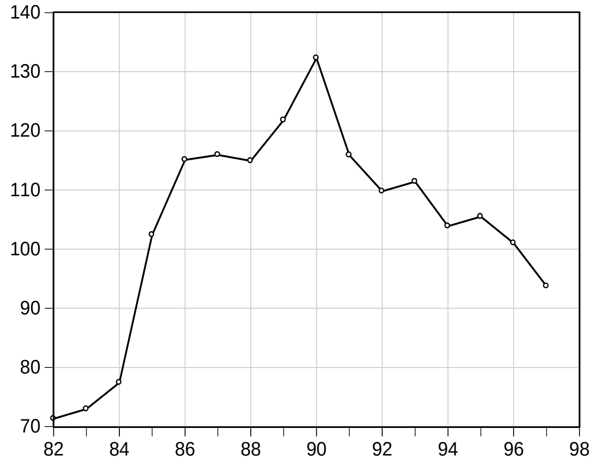
The Colombian elite were aided in the introduction of these reforms by historically low levels of growth throughout the eighties. Nevertheless growth was consistently positive; which contrasts markedly with most economies within the region. Following a long period of depreciation the reforms started in a period of historically devalued exchange rates (Graph 2), but with accompanying high inflation. Consequently in 1991 the authorities tightened monetary and fiscal policy, and there was a marked revaluation and reduced GNP growth.

Graph 2; Key Macro Variables

GNP Growth
Base 1975 =100



Real Exchange Rate
Base 1975 =100



Source: DNP (Colombian Department of National Planning)

On the back of these policies and liberalisation tax revenues increased, plus funds from privatisations and oil surpluses further boosted government coffers. This enabled the maintenance of support for the reforms through a marked increase in public spending. This inevitably led to increased domestic and foreign borrowing. There was then strong aggregate demand growth between 1992 and 1995. This was in spite of severe electricity rationing during the later half of 1992 and first quarter of 1993 as hydroelectric water reserves dried up due to El Niño. This growth and reduction in tariffs enabled a sharp deterioration in the current balance. The contemporaneous capital inflow fuelled a typical liberalisation credit boom that was most notable in construction and housing.

Monetary policy was again tightened post 1994 and controls, were placed on capital flows, these measured helped to reduce demand and the deterioration in the current account. There was also increased violence during the Samper presidency (1994-1998), nevertheless government spending continued to grow. A weak upturn from 1996 was swamped by the ripples of the Asian and Russian-Brazilian crises.

Growth rates up until 1997 were lower than those of the difficult 1980s, but we also see a falling GNP share for both manufacturing and agriculture. The non-tradable sectors of services, finance and construction grew much more strongly on the back of domestic demand.

3. Data and Methodology

The rich plant level database that we will employ was constructed by Eslava, Haltiwanger, Kugler and Kugler (2004) for their study of the effects of Colombian structural reforms on productivity and profitability enhancing reallocation using the Colombian Manufacturing Survey between 1982 and 1998[1] .

Their constructed series were calculated from the Colombian Annual Manufacturing Survey (AMS) between 1982 and 1998 and contains entries on over 12,000 plants. The AMS is undertaken by the Departamento Administrativo Nacional de Estadística (DANE) and includes data on plant level; output level and prices, inputs overall costs and individual prices, energy consumption (physical units) and prices; payroll and number of workers in production and non production and book values of equipment and structures.

Eslava et al constructed plant level price indices for composite output, materials and energy. These were then used to construct the physical units by dividing the value of output and the cost of materials by the corresponding prices. Plant capital stock in physical units was constructed from; $K_{it} = (1-\delta)K_{it} + \frac{I_{it}}{D_t}$ where *I* is gross investment, δ is the depreciation rate (based on "observed" rates at the 3 digit sector level); *D* is an implicit deflator of gross capital formation.

The AMS includes the number of workers but not employment hours and so they had to be constructed by dividing payroll for each sector by number of workers in each sector and then dividing the resulting measure of earnings by a monthly survey measure of sector wages (at the three digit level) to give a measure of sector hours. The corresponding sector hours is then multiplied by the total number of workers in each plant to give each plant's total employment hours. Further details are in their paper.

[1] We gratefully acknowledge the assistance of the Colombian statistical agency DANE and in particular Juan Francisco Martinez Rojas for allowing us to access this data, and of course Eslava et al for its construction.

This dataset then permits the construction of our plant level production function, in logarithms

$$y_{it} = +\beta_l l_{it} + \beta_\lambda m_{it} + \beta_e e_{it} + \beta_k k_{it} + \mu_{it} + \psi_{it}$$

where y_{it} is production from the *i*th plant in *t* period in thousands of 1982 Pesos; ***l*** is labour total hours as outlined above or simply the number of employees; ***m*** is materials usage, a composite weighted value in thousands of 1982 Pesos; k is capital also in thousands of 1982 Pesos and finally ***e*** is energy in kilowatts per hour.

The robustness of our findings is increased by the use of this value and volume data. The extra dimension reduces the simultaneity bias,[2] which results from our inability to observe time variant and plant specific heterogeneity. Plant heterogeneity tends to be under estimated by typical studies which only have access to value data and consequently use industry level deflated sales revenue, capital spending and input expenditure. The bias is most evident in the coefficients of more flexible control (endogenous) variables such as material inputs or electricity that can be adjusted more quickly in response to productivity shocks. We should also obtain more constant scale estimates, as they tend to be biased downwards when only using deflated value data.

A further source of endogeneity is selection bias, which is the result of plant exit. This bias becomes increasingly important with panels that cover greater time periods. Plants are seen to continue production if discounted profits exceed the sell off value. We can see that unobservable (to us) productivity will play a part in this decision. The bias becomes evident in the coefficient on capital. Larger plants will be more able to weather lower productivity than smaller plants given that their greater output volumes should lead to greater revenue. This would then lead to a negative correlation between productivity and capital as following exit due to lower productivity the level of capital would increase.

Methodologically we further account for simultaneity (and selection) problems by incorporating and modifying recent developments in techniques that allow us to maintain our plant level analysis. We do this using the dynamic non-parametric algorithm approach

[2] The simultaneity problem arises because some of the regressors are endogenous and therefore likely to be correlated with the error term. This arises in part because input choices are determined by a firm's beliefs about its own productivity, which we can not observe. This effect shows up in the error term and results in a positive correlation between inputs and productivity and other shocks that will lead to upwardly biased estimates of input coefficients, which may not be efficient or consistent.

developed by Olley and Pakes (1996), and modified by Levinsohn and Petrin (2003, henceforth LP) for developing countries. This approach is seen as relatively straight forward and robust compared to traditional fixed effects or instrumental variable methodology.

Eslava et al (2004) controlled for simultaneity using plant level input prices, regional government expenditures and downstream demand shifts, as instrumental variables. The prices of energy and materials were seen to be negatively related to energy consumption and material use but likely to be uncorrelated with productivity shocks. The downstream demand instruments required the use of input-output tables. These tables did not use ISIC codes and so concordance was only possible at the less specific two digit level.

There are concerns about the use of prices as instruments. Ackerberg, Benkard, Berry and Pakes (2005) show that there are a number of issues with the use of prices if input markets are not perfectly competitive. Market power will lead to differences in the prices that plants face. Prices will be related to the volumes that plants purchase, which will in turn depend on their levels of productivity. Price will then not be orthogonal to the error term. The IV approach may then fail to deal with selection bias. Input prices will form part of the exit decision based of profits relative to any plant sell off value. That may mean that higher prices are correlated with higher productivity in continuing plants.

Beyond these criticisms of the instrumental variable approach LP found IV procedures biased when compared to their methodology. Nevertheless Karacaovali (2006), a colleague of Haltiwanger, states that the use of plant level input prices negates the need to employ estimation techniques of the type proposed by LP. However, given that we have access to the same prices and the continued existence of bias we can directly incorporate the price series and test their validity as instruments.

The LP approach is of course not free from criticism. On the theoretical side we have made the logical step of removing the non transmitted error term (obtained after estimation of the coefficient on the exogenous variables) from the construction of the productivity proxy (see below) and consequently from the moment conditions. This should add to the stability of estimates, which is seen as a problem for the LP algorithm. Ackerberg, Caves, and Frazer (2006) have recently made this same point. These same authors have also pointed to a serious collinearity problem in these first stage procedures. Logically they anticipate that there should be limited independent variance between the exogenous variables and those within the non-parametric function.

L&P see labour, energy or materials inputs as perfectly variable and non-dynamic variables chosen simultaneously in the current period. However, a plant's use of these inputs is probably a function of capital and productivity, which in turn are determined by the past value of the proxy i.e. labour, energy or materials[3]. This chain shows then that the exogenous variables may not be identified. The net result is inconsistent estimators of the non-proxy variables. It is also makes estimates sensitive to small changes in the data.

On the mitigating side, we have a very large plant level panel covering a substantial portion of Colombian manufacturing. This additional dimension of plant level data should further mitigate collinearity. Plus the use of the fixed effects panel approach over LPs' use of standard OLS regressions should help mitigate the effect as even if variables are highly correlated in their levels there is no a priori reason why their deviations from plant level means should be highly collinear (Gujarati 2003). Nevertheless, we plan to test (in the future) the extent of any inconsistency through the use of Wooldridge's (2005) one step estimation methodology which should avoid this collinearity issue.

In order to implement our modifications we wrote our own Stata algorithm[4]. Beyond subtracting out the non-transmitted error term we incorporated panel data procedures to better capture plant level effects which are typically swamped by the between panel variances. Further we incorporated an appropriately weighted GMM procedure over which iterations were run to estimate the endogenous variable coefficients and obtain an estimate of TFP. This allowed us to experiment with the price series along side the use of lagged values of inputs. All of which is not possible if you use the LP & Poi (2003) Stata algorithm.

The use of fixed effects has of course also been criticised because it assumes all unobservables are time invariant. However because we calculate productivity as a monotonic

[3] The methodology requires that one of the free variable inputs acts as a proxy for unobservable productivity

[4] LP & Poi (2003) wrote a Stata algorithm which we also employed. We found unstable results that varied little from pooled and fixed effects estimation. This made us consider the possibility that we were not accounting for endogeniety bias. Crucially we also found that the estimated productivity did not have a monotonic positive relationship with the proxy (materials or energy in this case), when capital was held constant. This indicated a breakdown in a fundamental assumption. In spite of these concerns the programme still gave us estimates not wholly out of line with two recent studies using the LP methodology on Colombian data for similar period (table 4).

function of an observable proxy and capital inputs we can estimate TFP as time variant. We also have a long 17 year panel which overcomes some of the downward bias in the estimation of the coefficient on capital.

3.2 Methodological Procedures

The logarithmic version of the production function is:

$$y_t = f_t'\lambda + \mu + \psi_t \tag{1}$$

Where y is output, f is the vector of inputs, λ is the corresponding vector of coefficients capturing input elasticities, μ is a constant parameter (the mean component of the total factor productivity), and ψ is the disturbance term.

Following Olley and Pakes (1996) and LP (2003), we assume that $\psi_t = \omega_t + \eta_t$ where η_t is iid $(0, \sigma_{it}^2)$, a white noise shock/disturbance and ω_t is the so called transmitted part. The latter is the unobservable noise that signals to the plant regarding its output decisions and use of control inputs.

We partition f, the vector of inputs, $f' = (z', x')$ where x includes those inputs that are related to ω_t – i.e., the plant adjusts x_t using the signal ω_t – and z includes those inputs that are not correlated to ω_t. Thus, provided there is; (One) a positive monotonic relationship between productivity and the proxy, given capital, and (two) that productivity is the only unobserved state variable that causes differences in firm behaviour at a given point in time, we can postulate $\omega_t = \omega(x_t)$, where productivity is then a function of observable inputs.

Nevertheless, given the endogeneity of the x variables, (1) cannot be estimated consistently using the least squares approach. Consequently we undertake these steps.
Using the above description, $f' = (z', x')$ and $\lambda' = (\gamma', \beta')$ we rewrite (1) as

$$y_t = z_t'\gamma + x_t'\beta + \mu + \omega_t + \eta_t \tag{2}$$

Defining ϕ as $\phi_t = x_t'\beta + \mu + \omega_t$ (3)

We can also rewrite (2) as $y_t = z_t'\gamma + \phi_t + \eta_t$ (4)

If we take expectations of (4) conditional on x_t we have $E\left[y_t|x_t\right] = E\left[z_t'|x_t\right]\gamma + \phi_t$ (5)

Since $E\left[\eta_t|x_t\right] = 0,\ E\left[\phi_t|x_t\right] = \phi_t$ hold

In order to obtain consistent estimates of expectations the most straight forward approach is to treat ϕ non-parametrically. This makes the specification of ϕ more straightforward as we avoid the need to define demand functions and macroeconomic state variables. As LP and Poi (2003) we regress output and the exogenous variables on a third order polynomial expansion of the proxy and capital variables. This was instead of local quadratic smoothing techniques which are not reliably available in Stata 8. LP and others have found that both routes produce similar results. If time permits we may experiment with local quadratic smoothing techniques available in the R package. However, differently to LP and Poi, we incorporated plant and time effects so as to fully explore within plant relationships and further control for macro economic state variables.

We now define:

$\tilde{y}_t = y_t - E[y_t \mid x_t]$

$\tilde{z}_t = z_t - E[z_t \mid x_t]$

Then subtracting (5) from (4) yields $\tilde{y}_t = \tilde{z}_t'\gamma + \eta_t$ (6)

LP run a no constant OLS regression at this stage to obtain the coefficients on the exogenous variables. We again use panel fixed effects noting that plant effects and therefore the constant are now not significantly different to zero, giving us a regression in line with LP.

We can now analyse the impact of the inputs in *z*, but we are still not able to make any comments on total factor productivity or the returns to scale aspects of production inherent in the data. To do so, we need to obtain estimates of μ and β. This involves estimation of (2), where the dependant variable is output less the affect of the exogenous variables, namely

$$\left(y_t - z_t'\hat{\gamma}\right) = x_t'\beta + \mu + \omega_t + \eta_t \quad (7)$$

From which we can then calculate ϕ_t, which we defined in (3), and then use it to generate the initial parameters on the endogenous variables that are subsequently iterated over using GMM.

To estimate the relevant coefficients we can use (3) to rewrite (2) as

$$y_t = z_t'\gamma + \phi_t + \eta_t . \tag{4}$$

From (4) we can obviously obtain an estimate of; $(\phi_t + \eta_t)$ namely,

$$y_t - z_t'\hat{\gamma} = \widehat{(\phi_t + \eta_t)} \tag{8}$$

We then combine (4) with the estimate of η_t, i.e. $\hat{\eta}_t$, that we have already obtained from (6) to get an estimate of;

$$\hat{\phi}_t = \widehat{(\phi_t + \eta_t)} - \hat{\eta}_t$$

This last equation marks a modification of LP's methodology, who did not subtract out $\hat{\eta}_t$.

We now come to the crux of the estimation methodology. We noted that μ, the constant mean component parameter of total factor productivity, and ω_t, the transmitted component, are unobservable. Consequently in order to account for their causal impact on output we construct a proxy for them.

We define the proxy as $\hat{\zeta}_t$ for $(\mu + \omega_t) \equiv \zeta_t$ where $\zeta_t = \hat{\zeta}_t + \varepsilon_t$ (9)

We can therefore rewrite $(y_t - z_t'\hat{\gamma}) = x_t'\beta + \mu + \omega_t + \eta_t$ (7)

In the following manner;

$(y_t - z_t'\hat{\gamma}) = x_t'\beta + \zeta_t + \eta_t$,

$(y_t - z_t'\hat{\gamma}) = x_t'\beta + \hat{\zeta}_t + \varepsilon_t + \eta_t$,

& hence; $(y_t - z_t'\hat{\gamma}) = x_t'\beta + \hat{\zeta}_t + v_t$ (10)

Where $v_t \equiv (\varepsilon_t + \eta_t)$

If the initial coefficients on the endogenous variables are denominated by $\hat{\beta}^0$, then;

$$\widehat{(\zeta_t + \eta_t)} = (y_t - z_t'\hat{\gamma}) - x_t'\hat{\beta}^0$$

And then using $\hat{\eta}_t$ obtained from (6) we construct the proxy; $\hat{\zeta}_{0,t} = \widehat{(\zeta_t + \eta_t)} - \hat{\eta}_t$

Again we deviate from LP by subtracting an estimate of errors to improve the stability of estimates.

Productivity is seen to follow an exogenous first order Markov process, in that decision on investment and any change in state variables is taken with the information set available in t-1. Therefore we can estimate a productivity proxy by $E\left[\zeta_t \middle| \zeta_{t-1}\right]$. In order to construct the initial values we use the initial coefficients on the endogenous variables such that $\phi_t = x_t'\beta + \mu + \omega_t = \zeta_t + x_t'\beta$, and $\hat{\zeta}_{0,t-1} = \hat{\phi}_{t-1} - x_{t-1}'\hat{\beta}^0$ We then set the proxy as the fitted value obtained from regressing $\hat{\zeta}_{0,t}$ on $\hat{\zeta}_{0,t-1}$ and up to third order polynomials. We then denote the fitted series as $\hat{\zeta}_t^1$. We again also incorporate fixed and time effects.

We can also extract from this regression an estimate of the plant level constants.

$$\hat{\pi}_i = \bar{\hat{\zeta}}_{it} - \hat{\tau} - \overbrace{(\hat{\rho}_1\hat{\zeta}_{i,t-1} - \hat{\rho}_2\hat{\zeta}_{i,t-1}^2 - \hat{\rho}_3\hat{\zeta}_{i,t-1}^3 - \hat{\delta}_t TD_t)}^{-}$$

Where;

$\hat{\pi}_i$ Represents the plant level constant,

$\hat{\tau}$ The mean level of fixed effects/constant and,

and *TD* relevant time dummies

We now use (10) to estimate β by specifying the appropriate moment conditions, i.e.

$$E\left[v_t(\beta)w_t\right] = 0 \tag{11}$$

Where $v_t(\beta) = y_t - z_t'\hat{\gamma} - \hat{\zeta}_t - x_t'\beta$ – from (10) – and w_t is a vector that includes all the appropriate conditioning variables (instruments and exogenous/predetermined variables). Clearly, the dimension of w_t ought to be at least as large as that of β in order to satisfy the identification condition and the over-identifying restrictions which are imposed by choosing to include more elements in w_t than those in β ought to be intuitively reasonable and tested if possible.

We let $v_t(\beta) = a_t - x_t'\beta$ where $a_t = \left(y_t - z_t'\hat{\gamma} - \hat{\hat{\zeta}}_t\right)$, form the moment conditions and use GMM iteration to estimate β and consequently update the productivity proxy. We use a true GMM procedure and a variable set of IVs, whilst the LP & Poi (2003) algorithm uses a grid search in which the errors from a standard OLS regression are matched against a fixed set of IVs.

4. Choice of Control Variable

Olley and Pakes (1996) used investment conditional on capital to proxy (partitioned *x* variables) for the correlation between input levels and the unobserved productivity shock. However, investment may not be appropriate when analysing data from developing countries. LP (2003) show with the use of Chilean data that investment may not be sufficiently consistent (greater than zero). They found that if they had used investment with Chilean data well over 50% of the sample data would have had to be truncated. There would also be kinks in the investment demand function due to adjustment costs that cause delays and/or limitations in a plant's responses to productivity shocks. There would then still be a correlation between regressors and the error term. In the Colombian context there were interest rate caps and subsidies for specific industries in place pre 1991 which would have rationed access to capital depending on plant size/contacts and so forth and meant that plants may not have responded fully to productivity shocks, and this could mean that bias remains. Consequently it would then seem reasonable to adopt an approach based on more consistent intermediate inputs, which are much less costly to adjust.

The intermediate proxy must still meet the monotonicity condition, conditional on capital. Profit maximizing behaviour would imply that the more productive plants use more intermediate factors[5]. This is much easier to check than with investment but it may vary across industrial sectors. Levinsohn suggest three specification tests to help in the choice.

The first is to check that productivity shocks increase in the use of the intermediate inputs, holding capital constant; That is eyeball $\omega_t = \omega_t(m_t, k_t)$ (if we assume materials is used as the proxy). As this function may differ across sub periods we can see non-parametric approaches gaining in value as an estimation tool. The next is to test whether estimates are the same whether materials or electricity are used as the proxy. Finally we can test that all inputs are not correlated with productivity innovation in the next period. As shown above, one of the moment conditions is that the lagged value of freely variable inputs are not correlated with

[5] That is, for a given output level, plants would use less factors, but those with above average productivity (greater marginal productivity of inputs) would be expected to gain market share and expand output as they would have lower prices than those with higher production costs. Furthermore if a market is characterised by elastic demand, then inputs dominate productivity shocks; as such input usage will increase when there is a positive productivity shock. If plants' efficiency levels differ, and some plants' productivity increases more than the average they may well, ceteris paribus, capture greater market share. (See Klette J & Griliches Z (1996))

innovation in productivity in the subsequent period. Such conditions are part of the identifying conditions.

Before any of these tests, we can look at the number of non- zero observations so as to see how the use of a particular variable would truncate any estimation. It is not surprising that the non- zero observations of labour, electricity and materials are quite low as for a plant to enter the AMS a minimum production value must be met. If zero values represent kink points in factor demand and these are limited then we are more likely to meet the monotonicity condition.

Table 2: Percentage of non-zero Observations

Investment*	45.15%	Nearly all other values are less than zero
Energy	99.72%	99.46% use more than 2MW
Materials	99.47%	
Labour	100%	11.6% report ≤ 20,000 hours

Here Investment is differenced Capital Stock
Eslava et al (2004) data set, author's calculations

It is assumed that the factors are freely available. This may have been problematic for electricity in Colombia with technical power losses and guerrillas targeting electricity pylons. There were significant blackouts in 1983 and 1992-1993. Pomo and Taborda (2006) show how efficiency has increased only amongst the most efficient electricity distributors since the partial privatisation of generation and distribution in 1994. They also show that average industrial electricity prices (there were marked regional differences) rose less than 1% in the 5 years 1991 to 1996 over the period 1985 to 1990 and then fell substantially in the period 1997 to 2001. It is also interesting to note that profits increased through better billing, which impacts directly on plants. Unreliable supply may mean production slow downs as local generators are employed.

Materials are affected by interruptions due to communication problems from the road network, weather conditions or civil conflict delaying supplies. Materials though have a further problem in that they can be stored and this reduces their correlation with current productivity.

Finally we could also include labour as a state variable if we decide that it does not respond freely to current changes in productivity. Schor (2004) made this decision when looking at Brazilian manufacturing, noting that workers hours would initially respond to shocks, but these would be incomplete due to high dismissal costs. We have the choice of worker numbers or the freer adjusting total number of hours.

6. Descriptive Analysis

The Colombian Manufacturing sector underwent significant changes in both the 1980s and 1990s. Table 3 and graphs 3 to 7 shows that there was positive output growth throughout the 1980s both for overall manufacturing and for the mean plant. This was reflected in the positive annual net plant entry of around 2% in the later half of the 1980's. These plants tended to be much smaller than the average, as we see in the fall in average plant employment. This growth however was not reflected in the employment levels which were all but static in this period after a heavy fall in the slow down of the early 1980's. We also see initial leaps in capital stock, followed by growth above output growth rates. These combined to give a rising capital labour hours ratio, with capital the stronger influence.

In spite of the removal of many non-tariff barriers and small falls in tariff levels import participation in local markets was only between 4 and 5% in the resource and labour intense sectors and 25% in the capital intense sectors. The growth in import penetration was negative until 1986 and then less than 1% until 1990 with a continually devaluing Real Peso from a high level (graphs 2). At the time labour intense sectors had mean tariff rates of 55% whilst those of the other sectors were below 40%.

To get a feel for the degree of Structural change we use Reinhardt and Peres' (2000) index., which measures the overall shift in output share, that is;

$$SCI = \sum_j \left| s_{je} - s_{jb} \right| / 2$$

s_{je} is the share of sector *j* (4 digit ISIC sectors) at the end of a period and s_{jb} is the share of the sector at the beginning. This index varies between 0 (no change) and 1 (complete change). The capital and labour intense sectors saw structural change of 0.15 and 0.14 respectively in the latter half of the 1980s whilst the resource intense sector was relatively stable with a change of 0.07.

The reform years from 1991 saw output growth at a lower level than the 1980s. This was mainly confined to the GNP growth acceleration from 1992 to 1994. Graphs 3 (pp 20), show total output for those plants within the inter-quartile range for each year. Also in graphs 3 this is disaggregated by sector factor intensity, within the annual IQR of output, graph 3 and for all plants in graph 4 and output is also further disaggregated for the five largest three digit sectors also in A3. We have used output both in logarithms and within the IQR to control for some extreme and or erratic values that obscure the median experience.

One surprising aspect is that output grew during electricity rationing. This was in the capital and resource intense sectors, whilst labour intense sectors experienced a fall in output. As Rationing occurred during an up turn in GNP we see a significant spike in labour intense imports (graphs 5). We also see a sharp fall in the capital labour hours ratio across all factor intensities as extra labour is substituted for electricity (graphs 7). After the rationing, output continued to fall on average for all labour intense plant, whilst for those within the median range there was a mild recovery in 1993 and 1994, but this did not offset the overall reduction in total output.

The capital and resource intense sectors maintained above GNP growth rates until 1995 when they saw negative growth; this preceded the downturn in GNP growth. Through the 1980s up to 1994 there is a general growth above, in synch with GNP. But with labours divergent pattern and greater levels of imports this link breaks down in the 1990s.

All factor intensities saw the number of plants fall (appendix graphs A2 and A5). Exits peaked in 1991, but continued to fall throughout the period. However many more Labour intense plants exited than from other sectors. The actual number of labour intense plants followed the pattern of trade tariffs very closely; rising with them until 1985 and then slowly falling in the latter 1980s, before crashing in the 1990s. Labour intense plants typically have thin margins and this may explain the difference with other factor intensities. Plus it is much easier for these types of plants to become informal (textile home working is just one example).

In line with the fall in tariffs and a persistent real revaluation, imports doubled their market share in the labour and resource intense sectors (graphs 5 and 6), but rates were still on average below 10%, and with markedly lower coefficients of variance. These penetration rates subsequently increased quite dramatically in the latter years of the 1990s. In the capital/skill intense sectors the level of penetration shifted to an average of 35% and again higher from 1996. We will see below that some capital intense sectors attracted greater FDI which may have reduced import penetration, but this just shifted imports upstream.

All these changes resulted in a steep fall in worker numbers (graph 7); particularly in the labour sectors. This initially meant a rise in the average plant size (coupled with small plants exiting) but this trend was reversed post 1994. Over the 1980s the Eslava et al dataset captures a loss of 19,000 jobs, this nearly doubles to 33,000 between 1990 and 1996 and a further 33,000 are lost thereafter.

Capital stock changed at rates above those of the late 1980s and of output growth. This was helped by a strong one year spike in 1994, after which there was a marked downturn (graph 7). Average levels of capital stock also grew due to the large number of plant exits. These changes, plus the falls in output contributed to the descent in output to capital ratio across all sector intensities through out the 1990s (graph 7). This would indicate generalised leftward shifts along possibly lower average cost curves.

In line with these changes we see greater positive growth in the capital labour hours ratio, especially post 1994. After 1994 worker hours dropped at an increasing rate whist capital stock increased by around 5%. The fall in labour became more relevant for this ratio than the 1980s, (table A1, appendix).

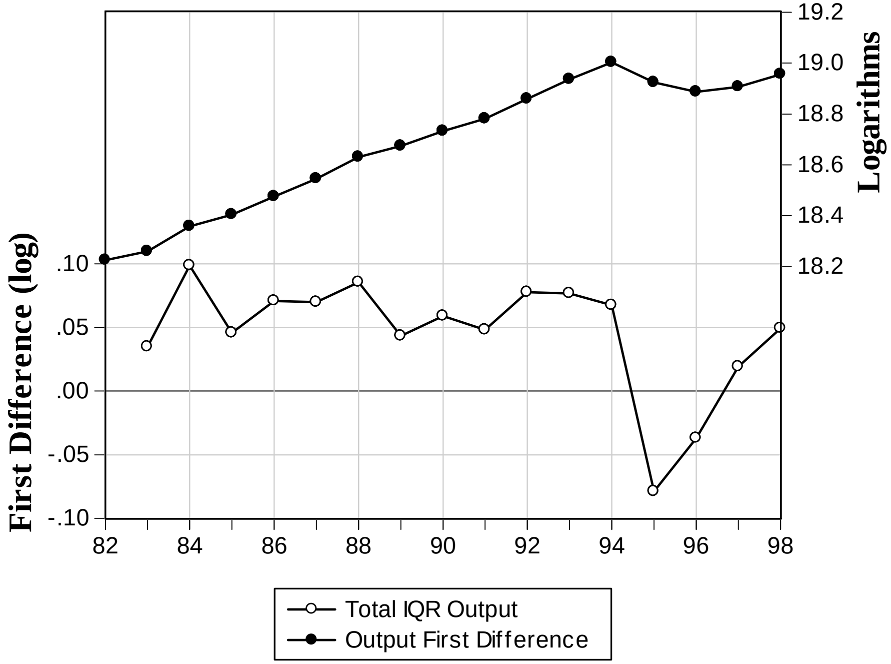
Taken together, these changes demonstrate how selection bias would typically bias downward the capital coefficient. Lower output leads to lower productivity (see below) and onto the exit of smaller plants; giving a negative correlation between productivity and capital.

Disaggregating by sector factor intensity, it would seem that liberalisation had its biggest impact in the labour intense sector; even though imports were still relatively low. Nevertheless structural change in the labour intense sector was 0.07, on the structural change index, which is half that of the 1980s, probably indicating a generalised decline. Structurally the other sectors seem to follow changes that had begun in the 1980's. The capital intense sectors saw continued strong reallocation of activity across sectors, whilst the resource intense sector saw a consistent level of change in spite of increased exits. This possibly indicates that imports were replacing the exiting plants and the some of the production of the continuing plants across the majority of four digit sectors.

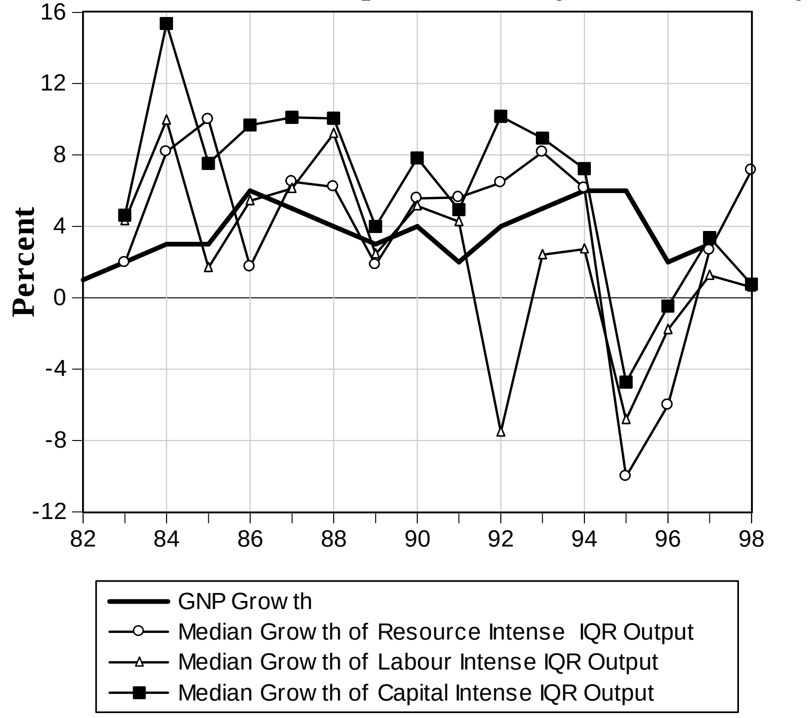
Table 3: Descriptive Data Summary											
Factor Intensity [A]	Years [B]	Mean Output Growth Rates	Mean Output Share	Mean Labour Growth Rates	Mean Plant Employment	Mean Capital Stock Growth Rates	Capital/ Labour Hours Ratio Growth	Mean Nominal Tariff	Mean Import Penetration [C]	Net Entry [D]	Structural Change Index [E]
Resources	82-84	0.5%	34.7%	-2%	74	18.2%	22%	41%	5.3%	6.3%	0.05
	85-90	4	34	0	68	7.4	7.8	38	4.0	2.0	0.07
	91-94	2.9	36	1.8	77	11.5	8.9	19	8.1	-2.0	0.06
	95-98	-2.2	37.8	-3.4	68	8	12.9	17	11.4	-5.3	0.08
Labour	82-84	3%	33.4%	-1.4	69	15.3%	17.5%	79%	4.1%	9.2%	0.03
	85-90	4.6	34	-0.3	61	9	9.9	55	4.7	1.8	0.14
	91-94	-0.2	30	1	75	13	9.9	21	8.3	-4.8	0.07
	95-98	-3	28	-5.5	67	3.2	11.7	18	16.5	-7.8	0.1
Skill/Capital	82-84	7%	32%	-1.9	82	18.3%	21%	41%	29%	5.5%	0.08
	85-90	8	32	1.4	75	8.8	7.6	33	25.5	2.1	0.15
	91-94	6	34	1.9	82	12.3	9.1	14	35.4	-2.1	0.11
	95-98	-1	34	-4.5	72	6.1	12.6	13	42	-5.2	0.13
Overall	82-84	3.4%	-	-1.8%	75	17%	20%	54%	12.4%	7.0%	0.07
	85-90	5.5	-	0.3	68	8.4	8.4	43	11.0	2.0	0.12
	91-94	3	-	1.6	78	12	9.3	18	17.2	-2.9	0.1
	95-98	-2.1	-	-4.4	69	6	12.5	16	23.0	-6.0	0.12
Notes	A: division by three digit sector as calculated by Colombian Central Bank(ref) B: division by approximate economic cycle C: Imports/(Production + Imports – Exports) as calculated by DANE at ISIC 3 digit level D: Excludes 1982 & 1998 E: years overlap 82-84:84-90:90-94:94-98; level rather than logs to capture the large number of extreme values; 4 digit ISIC sectors Sources Eslava et al (2004) dataset; Factor Intensity from El Banco de la Republica; Import penetration figures from DNP; authors calculations										

Graphs 3: Descriptive Statistics: Total and Mean Plant (Logarithmic)

Manufacturing Interquartile Total (Log) Output & First Difference

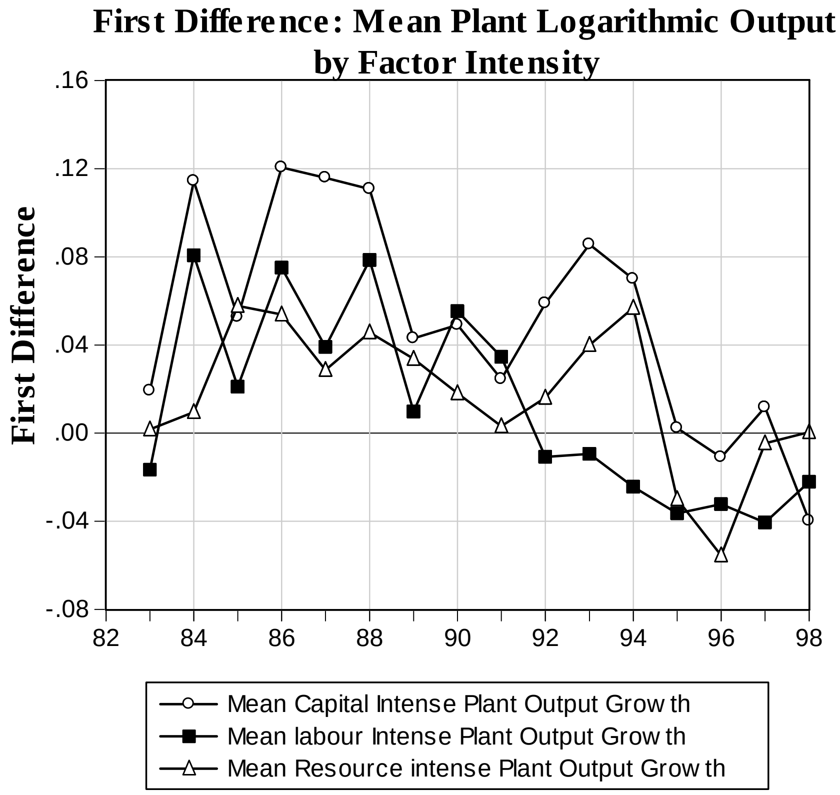


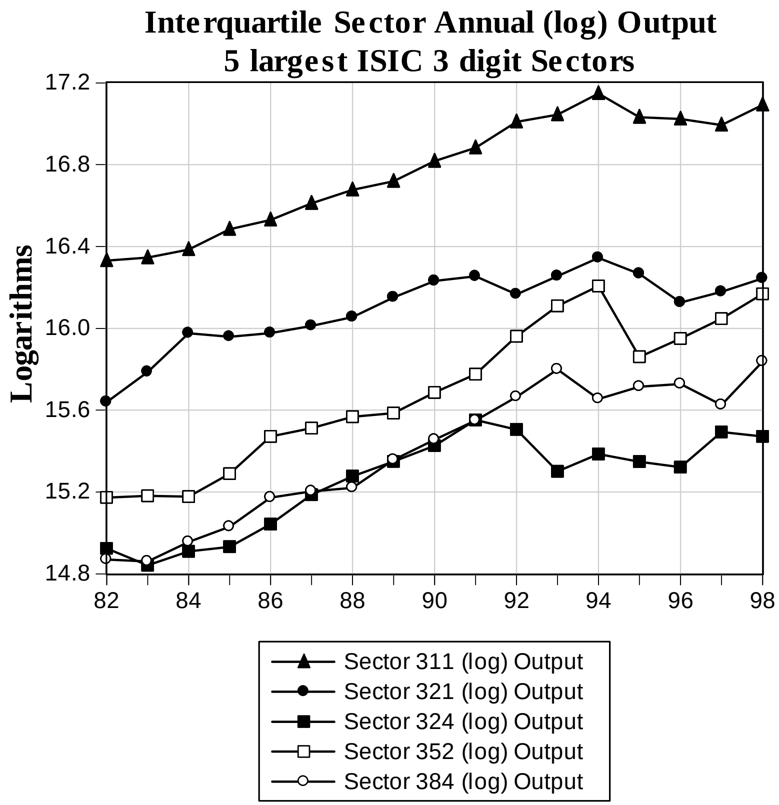
GNP & Annual IQR Output Growth By Factor Intensity



Source: Eslava et al(2004) dataset, Intensity defined by El Banco de la Republica; authors Calculations

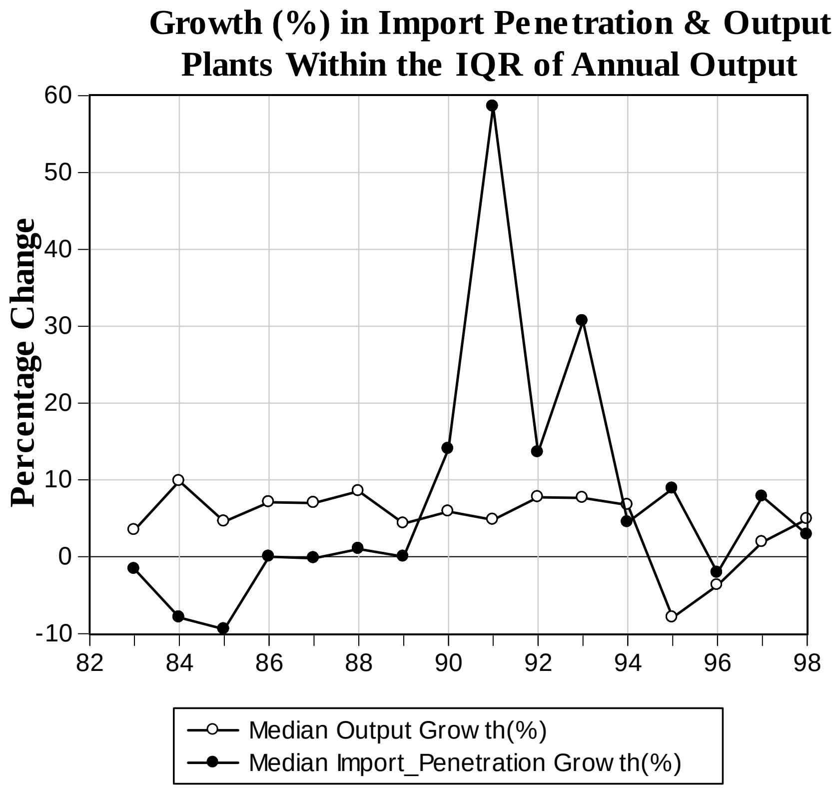
Graph 4 Disaggregated Output by Factor Intensity (all plants) and largest Three Digit Sectors (annual IQR)

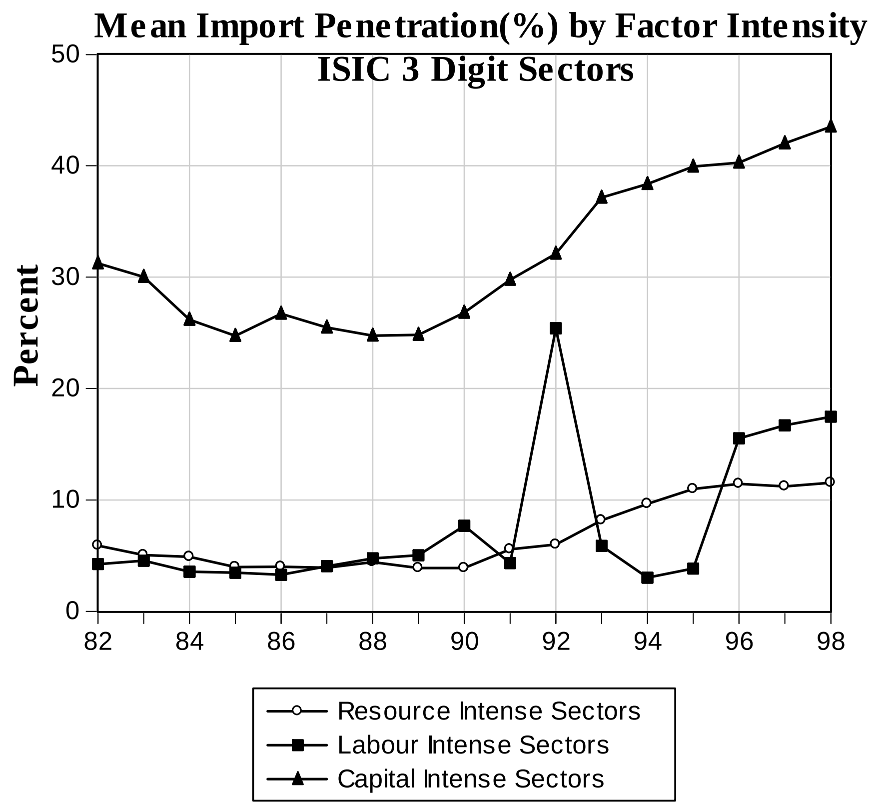




Source: Eslava et al(2004) dataset, Intensity defined by El Banco de la Republica; authors Calculations

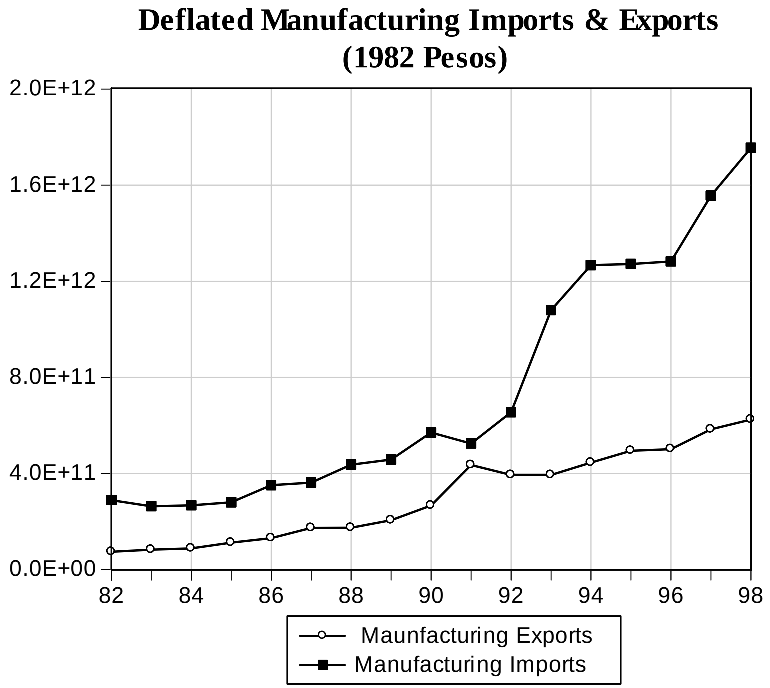
Graphs 5: Descriptive Statistics: Import Penetration & Output



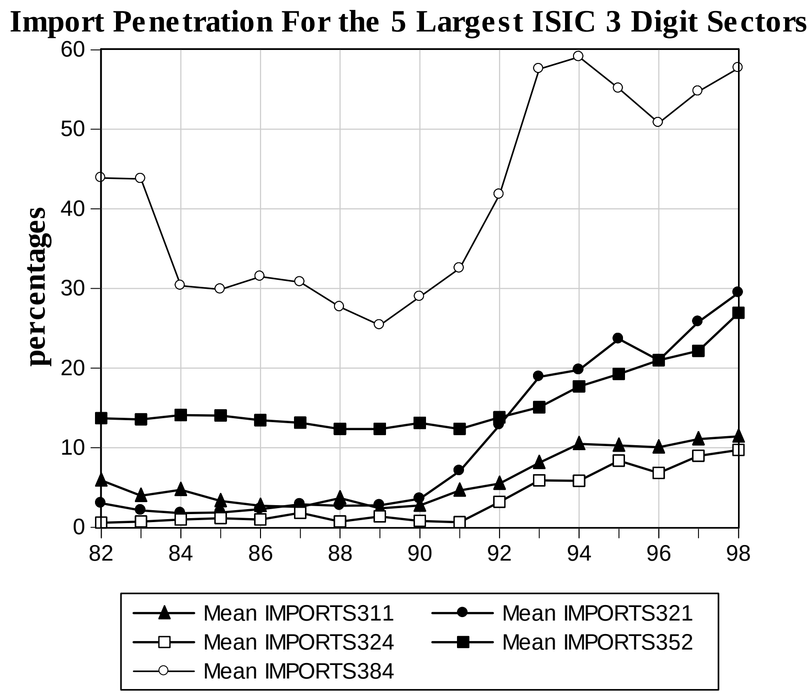


Import Penetration = Imports/(production + Imports – Exports)
Source: DNP (import penetration) & Eslava et al(2004) data set, authors Calculations

Graph 6 Imports & Exports

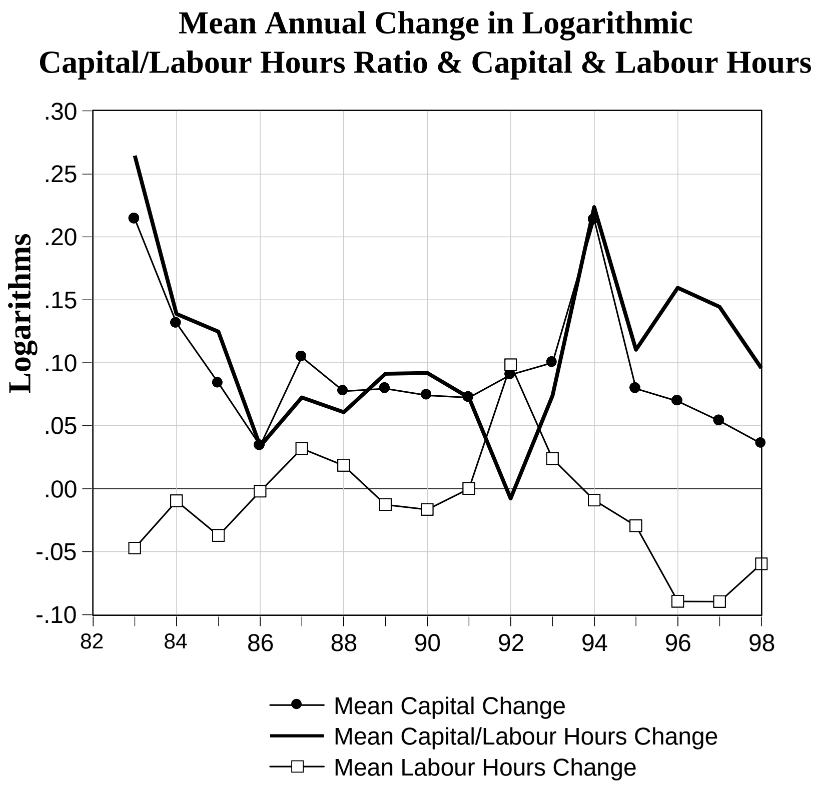


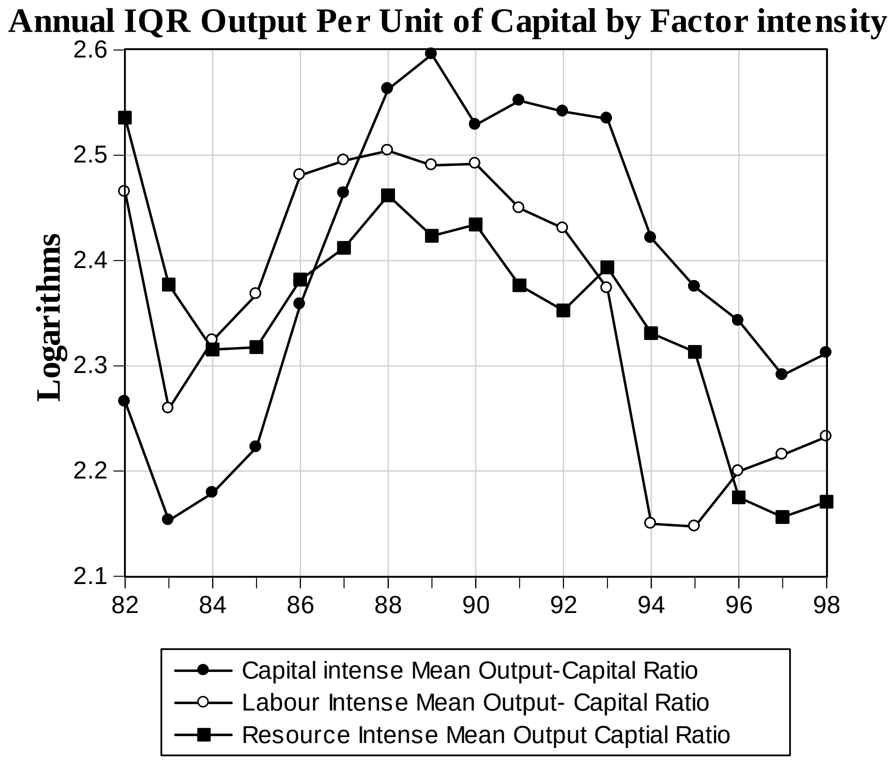
Source: DANE, Authors Calculations using Eslava et al Deflators



Source: Eslava et al(2004) dataset, Intensity defined by El Banco de la Republica; authors Calculations

Graphs 7: (log) Capital Labour Hours Ratio & Output Capital Ratio





Source: Eslava et al(2004) dataset, Intensity defined by El Banco de la Republica; authors Calculations

7. Estimation Results

We set out in table 4 (below) the different coefficients[6] on the key input variables across recent studies. Our results were obtained using a parsimonious set of instruments. We used a one period lag of the capital variable and one and two period lags of the proxy (here materials) based on guidance from the Hansen J statistic. This reduced set of IVs, compared to a set which also include lagged values of the exogenous variables, met the identify conditions. We also experimented with the use of input price indices, but these (at best) added little to the identification of the endogenous variables.

The most striking characteristic of ours and others *TFP* estimates is the substantive drop in 1992 (graphs 9 to11). This coincides with the full implementation of the liberalisation process but also the severe electricity rationing. In the work by Echeverría et al (2006) this drop is relatively quite small, whist the significant drop and subsequent fall in TFP found by Eslava et al (2004) is reversed after weighting TFP by three digit ISIC output share (we produce a similar pattern if estimation is in levels). Both of these papers found that TFP grew over the period.

We also weighted our series by market share as Eslava et al (2004), but also Olley and Pakes (1996) and Pavcnik (2002), that is;

$$Wtfp_t = \overline{tfp}_t + \sum_{i=1}^{i} (f_{it} - \bar{f}_t)(tfp_{it} - \overline{tfp}_t)$$

Where a bar represents a mean over all plants within a four digit sector for a given year and f represents domestic output share within the industry, i denotes each plant within the industry. If the covariance term is positive then greater output share is captured by the more productive plants.

After weighting we also found a positive effect on productivity, but it only shifted our TFP curve upward, and the 1992 drop was still very large[7]. Melendez and Seim (2006) find a very similar pattern. These authors also see little growth in TFP over the whole period. Furthermore Echeverría et al (2005) also report unweighted results very similar to ours during the 1990's.

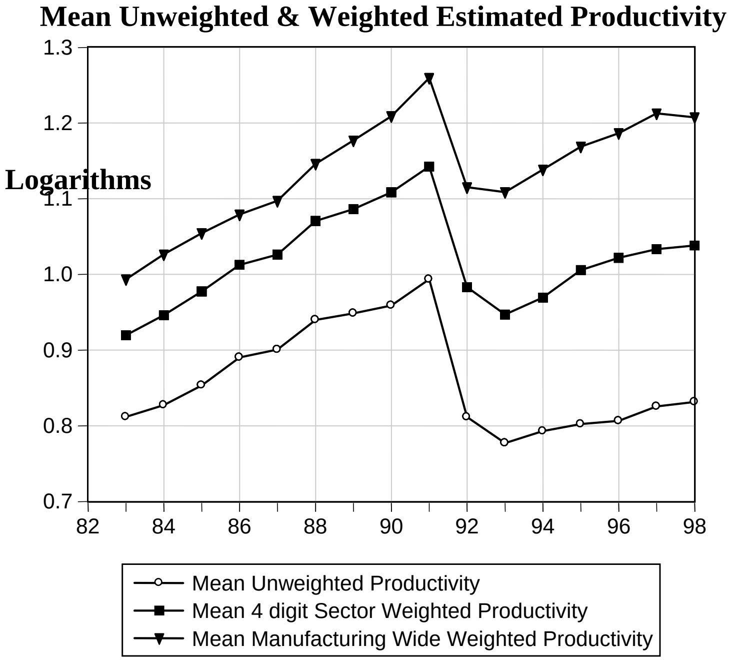
[6] The coefficients by sector factor intensity and for the 5 largest 3digit ISIC sectors are reported in the appendix
[7] We also estimated excluding 1992 observations and by averaging 1991 and 1993 observations for 1992, see appendix graph A5. This was to focus on underlying economic issues, but the drop was not removed.

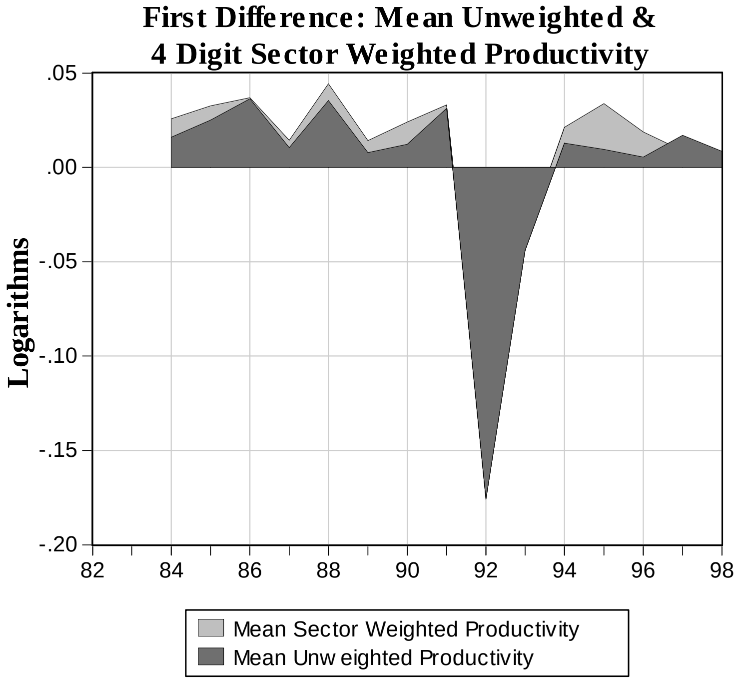
Table 4: Production Functions Comparative Recent Results						
Method / Log Inputs	*Using Eslava Et al Data set 1982-1998*				**Melendez-Seim 1977-2001 Levinsohn Petrin Methodology** [c]	**Echavarria, Arbelaez & Rosales 1981-2002 LP & Poi Programme**[d]
	Methodology In this Paper (Materials Proxy)[a]	**OLS (robust & cluster)**	**Fixed Effects**	**Eslava Et al (2004) 2SLS**[b]		
Labour	0.17 (0.008)	0.26 (0.009)	0.17 (0.004)	0.212 (hours)	0.11 (skilled) 0.16 unskilled)	(Skilled) 0.15 (Unskilled)0.14
Materials	0.62 (0.01)	0.59 (0.007)	0.58 (0.003)	0.275	0.41	0.54
Energy	0.06 (0.005)	0.1 (0.006)	0.08 (0.002)	0.175	0.08	0.07
Capital	0.13 (0.009)	0.08 (0.005)	0.04 (0.002)	0.302	0.11	0.41
	Constant returns p =0.03	**R^2** 0.85	**R^2 within** 0.55	**R^2** 0.81	-	-
Observations /Plants	61,495 / 6,560	76,330/ 6,566	76,330/ 6,566	48,114	122,118/ 14,806	78,661/ 8,916
Productivity Constant	0.29	-	-	-	-	-
Notes	***a:*** Labour hours; minimum 5/17 observations: materials proxy;500 iterations for standard errors In a balanced sample labour 0.21(0.01); materials 0.6(0.05); energy 0.06(0.01); capital is 0.15(0.03) constant returns (p=0.2); TFP constant 0.05; obs. 22635/plants 6560; 20 iterations ***b:*** IVs of local government/prices and downstream demand. Also reports labour hours ***c:*** Only 10 ISIC 3 digit sectors; materials as proxy; industry & whole economy deflators; ***d:*** Labour Numbers; capital weighted by capacity utilisation; Materials as Proxy; removed 5% extremes; industry deflators					

Over the period weighted *TFP* grew at a higher rate than the unweighted estimate, indicating consistent within sector reallocation productivity gains. Post liberalisation and energy rationing the gap was at its largest as plant numbers continued to fall.

During the 1980s, weighted *TFP* grew by 18.8% to which within sector reallocation contributed 4%. If we weight across manufacturing we add a further 2.7% growth (less than indicated by the SCI table 3). Post liberalisation the stronger within sector reallocation ameliorated the within plant productivity fall from 12.8% to 7%, whilst the across sector gains (shift away from labour intense sectors) counterbalanced the within plant productivity fall.

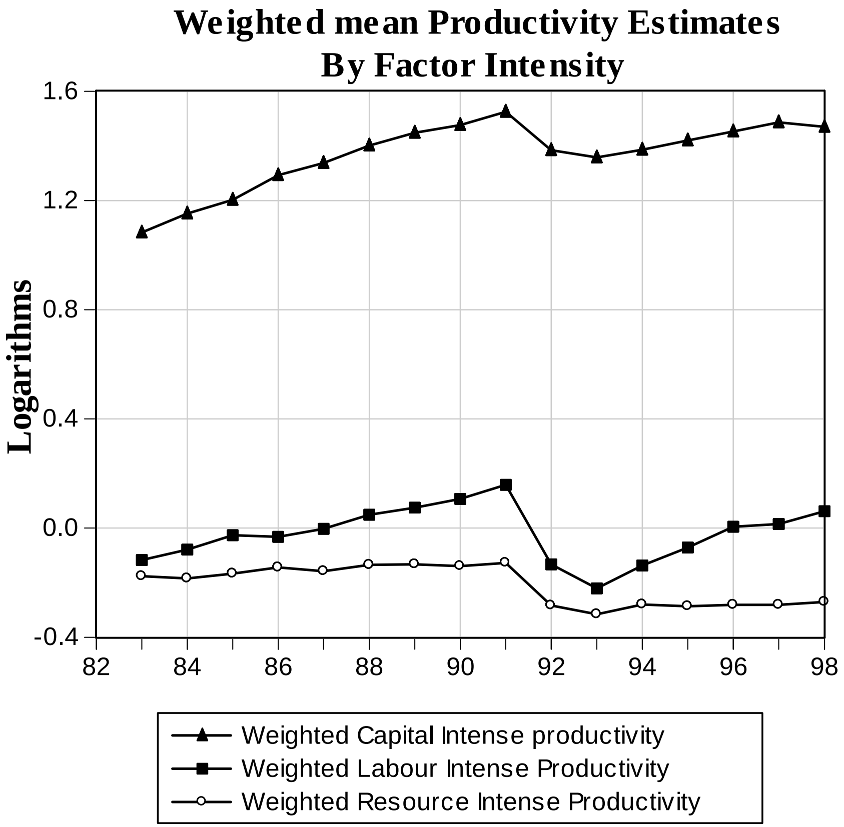
Graphs 8; Unweighted & Weighted Productivity

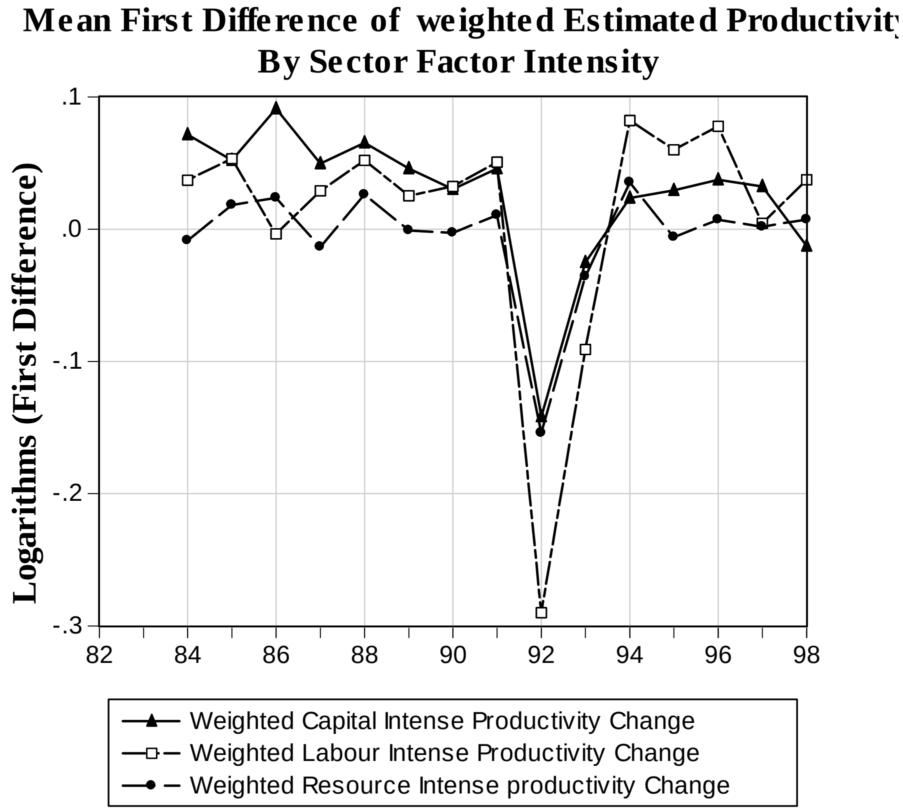




Source Eslava et al (2004) dataset, authors estimations

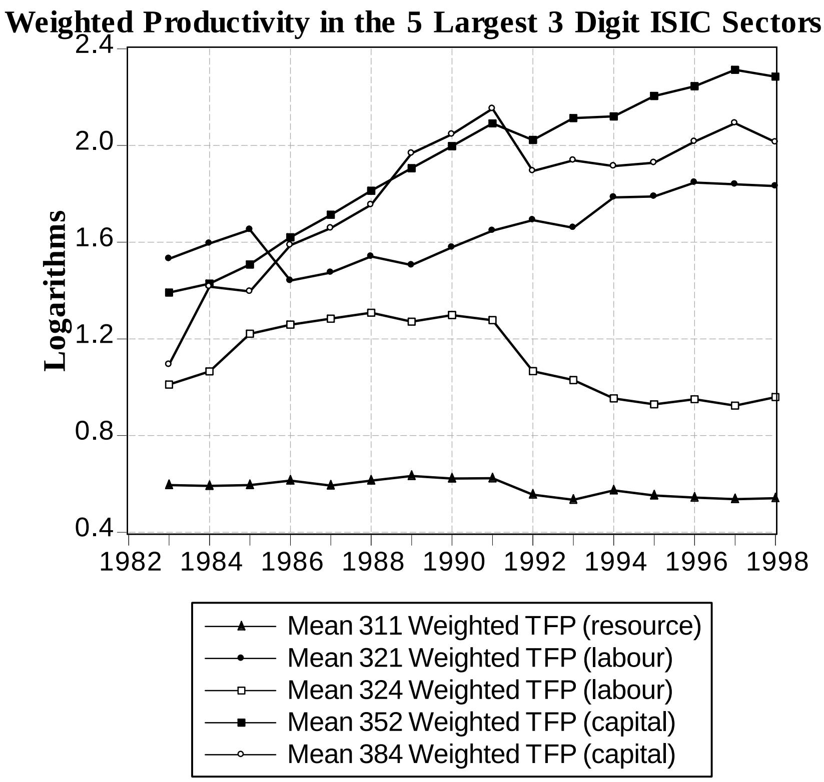
Graph 9; Weighted Productivity By Factor Intensity





Source Eslava et al (2004) dataset, Three digit Sector Intensity Division by Colombian El Banco de la Republica, authors estimations

Graph 10: Weighted TFP for The Five Largest Sectors



Source Eslava et al (2004) dataset, authors estimations

Looking at more disaggregated productivity series we can see that the overall pattern hides extremely divergent growth paths. Graph 9 shows that the capital sectors had productivity consistently a number of factor times greater than that of the other sectors and that it recovered more rapidly than that of the labour and resource intense sectors. Graph 10 shows the five largest three digit ISIC sectors, which represented a low of 38% of all manufacturing output in the mid 1980s and up to 51% by 1998. The largest of these was the resource intense 311 (food products) sector, which varied between 19% and 25% output share. The next sector was the labour intense 321 (textiles) with a stable 8.9 to 8.5. The third largest was the capital intense 352(other chemicals) with a rapidly growing share of 6.2 to 8.3. However in level terms the growth was even more dramatic. Labour intense 324 (footwear) had 4.6 to 4.8% and capital intense 384 (transport equipment) had 4.2 to 4.9. All the highest percentage figures are at the end of the 1990s, reflecting a lower rate of decline than other sectors, as much as any growth (graph 4).

The dominance of 311 is reflected in the overall outcome and in that of all resource intense sectors, which saw relatively little structural change. This lack of change is reflected in graph 12, which shows the difference between weighted and unweighted productivity. We can see that not only was the difference much lower than that for other factors but also much flatter, reflecting the changes indicated by the Structural Change Index. As such resource intense sectors saw 3.7% *TFP* growth in the 1980's, of which reallocation caused 2%. But a 1.5% reallocation gain in the 1990s hardly offset the within plant decline of 13%.

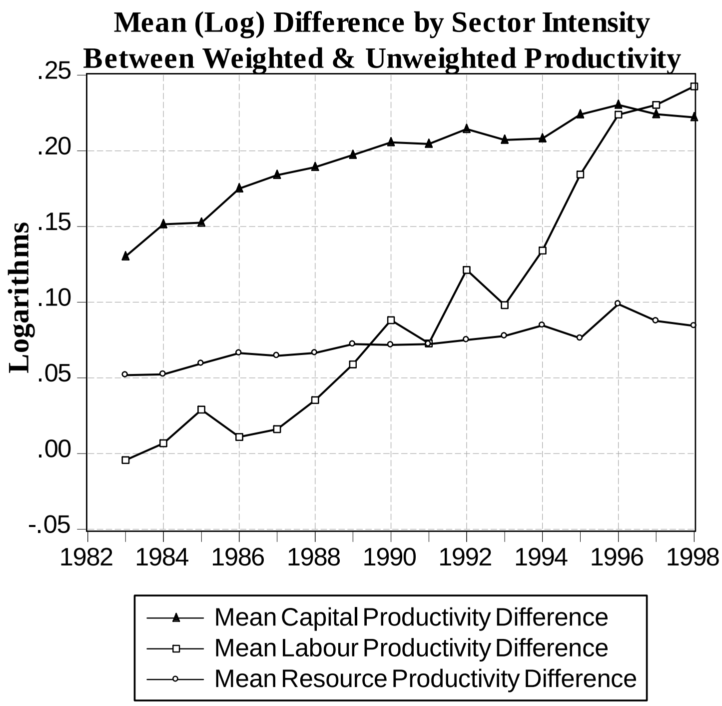
The labour intense sectors had a very different experience. Graph 11 shows how the large displacement of small labour intense plants drove a substantial shift in domestic output share towards larger plants and as such the strong divergence between unweighted and weighted *TFP*. Over the 1980s reallocation accounted for 9% of the 22% growth in productivity. During the 1990s reallocation reduced the productivity fall from 20% to 4.5%. At a three digit level we can see very different patterns.

The productivity of 324 (graph 12) clearly follows a similar pattern to that of its protective tariffs. As such any consolidation of activity in the sector was in the face of greater import penetration and falling output. Nevertheless 321 saw much more dramatic changes; more than double the level of trade intensity and a much bigger fall in output and a greater level of concentration. This produced an increase in productivity.

The structural change index also captured the substantial shift in the capital intense sector shares that clearly started pre liberalisation and are also reflected in graph 11. Between 1982 and 1990 capital intense sector productivity grew by 39%, of which 7.5% is attributable to reallocation. By 1998 productivity was still 0.5% below the 1990 level, with reallocation having boosted this figure by 1.5%.

At the three digit level, we again see different productivity patterns post liberalisation. During the 1980s sectors 384 and 352 enjoyed similar levels of productivity and growth (graph 12). Post liberalisation 384 saw a sharp and sustained fall, whilst 352 saw no change in *TFP* growth. Both sectors saw trade intensity double, but 384 faced up to 60% import penetration whilst that of 352 doubled to the mid 20% range. Capital labour ratios were similar and grew at similar rates. A key difference was FDI Flows. Sectors 38 (2 digit level) captured nearly 70% of FDI flows in the 1980s and 22% of the much larger flows post reforms. Whilst 35 (2 digits) captured 36% of the increased post 1990 inflows (table A2 and graph A4, appendix). This may help explain the big increase in 352 output compared to the fall for 384 (even though 384's overall share of manufacturing output increased).

Graph 12; Weighted & Unweighted Productivity Log Differential



Source Eslava et al (2004) dataset, Three digit Sector Intensity Division by Colombian El Banco de la Republica, authors estimations

Despite the reallocation of activity within sectors we still see that productivity did not recover strongly. The principle possibility for the slow recovery is the growth in imports. Post liberalisation import growth clearly outstripped that of exports and domestic output (graphs 5 and 6). The increased level of import competition may have caused a general leftward movement along plant average cost curves as market share was taken, and limited the ability to fully exploit additional capital stock; as we see in the fall of the output-capital ratio (graph 7). Of course, some sectors may have seen x-efficiency gains, but with an overall decline in within plant productivity we see no evidence of a generalised dynamic shift to a higher growth path.

In order to further explore the impact of greater trade intensity, we divided the DANE measure of apparent consumption measure[8] by its inter-quartile range (tables 5, 6a and 6b). Plants in the fourth quartile faced a relatively greater intensity of trade via greater import

[8] calculated by Colombia's DANE at the three digit ISIC level

competition and/or greater exports. Those in the first quartile faced much lower trade intensity, through either much less foreign import competition and/or lower exports. The mid range corresponds to inter-quartile range.

In table 6a we look to pinpoint the structural impact of liberalisation. We set out deviations (incorporating plant level constants) from the mean of unweighted productivity for a given period depending on a plant's factor intensity, trade intensity and size. In table 6b, we again construct deviations, but here they are only of plant level constants. This means we can isolate the impact of time invariant factors.

From table 5 the only obvious pattern in the input coefficients between these trade intensity divisions was a lower use of capital in sectors which faced relatively less trade. Nevertheless the coefficients on capital in these sectors increased in the 90s, whilst that for high trade intense sectors fell.

The composition of these relative trade intensity divisions shifted between decades as first non-tariff barriers and then nominal tariffs were reduced by different amounts for different sectors. Sectors 32 (textiles)[9] and 35 (chemicals - except 352) and 390(other) saw large increases in trade intensity (from low to mid or mid to high). These sectors all saw tariffs fall by around 60% in the early 1990s, with by the biggest percentage point drop for textiles and allied sectors from over 60% to under 20%.

Even with the generalised increase in imports and exports, the sectors 312(other food/animal feed), 341 (paper) 352 (other chemicals) and 361(pottery) saw their relative trade intensity move in the opposite direction. Sectors 341 and 352 for example attracted high levels of foreign involvement. 341 also saw a large percentage point fall in nominal import tariffs, whereas 352 already had relatively low average tariffs.

The pharmaceutical sector (3522) is an interesting case. It saw a change from high to mid range trade intensity as foreign companies came to control around 70% of capital (University Sergio-Arboleda). We show in table 6a this shifted the plants into a trade intensity range in which plants enjoyed the largest positive deviation (0.77) from mean *TFP*.

[9]321(textiles); 322 (wearing apparel, except footwear); 324 (footwear, except rubber or plastic) 354(Miscellaneous petroleum & coal products); 355 (rubber products) 356 (plastic products)

However we can not say that FDI was necessarily a key source of productivity growth. We have already seen that ISIC 35 attracted 36% of FDI flows during the 1990s, and that the apart from 352 the other three digit sectors saw either no overall relative change or an increase in trade intensity.

Table 5; Estimated Production Functions: By Trade Intensity

Trade Intensity/ Apparent Consumption [a]	Capital	Energy (proxy)	Materials	Labour	Constant Returns To scale [c]	Mean Period Plant Productivity Log Change	Obs. Plants	Period Net Entry (%)
1982-1990 [b]								
Low Trade	0.07 (0.025)	0.25 (0.02)	0.44 (0.03)	0.17 (0.02)	No P=0	0.16 (0.38)	7,593 1,633	6%
Mid Range	0.097 (0.009)	0.153 (0.004)	0.58 (0.01)	0.122 (0.02)	No P = 0	0.008 (0.03)	14,554 3,202	24%
High Trade	0.12 (0.02)	0.186 (0.02)	0.436 (0.02)	0.257 (0.009)	Yes P=0.98	0.045 (0.36)	9,585 1,815	-7%
1991-1998								
Low Trade	0.08 (0.26)	0.15 (0.023)	0.63 (0.009)	0.09 (0.02)	No p = 0	-0.017 (0.03)	6,158 1,289	-22%
Mid Range	0.13 (0.02)	0.09 (0.02)	0.65 (0.007)	0.15 (0.004)	No p = 0.04	-0.002 (0.03)	14,356 2,799	-12%
High Trade	0.10 (0.02)	0.14 (0.03)	0.52 (0.02)	0.18 (0.02)	No P=0	0.007 (0.03)	6,526 1,338	6%
Overall								
Low Trade	0.082 (0.017)	0.222 (0.007)	0.504 (0.016)	0.163 (0.015)	No p =0.01	0.003 (0.04)	14,205 2,340	-
Mid range	0.114 0.02)	0.108 (0.016)	0.638 (0.006)	0.143 (0.007)	Yes p =0.7	0.008 (0.04)	32,944 3,901	-
High trade	0.097 (0.017)	0.147 (0.03)	0.486 (0.005)	0.254 (0.027)	Yes P=0.49	0.03 (0.04)	16,809 1,974	-

a: Trade Intensity/Apparent Consumption = imports/(domestic output + imports – exports)
b: Where Low; mid: high correspond to first quartile; inter-quartile range; fourth quartile of mean 3 digit ISIC sector import penetration for the specified period.
c: decision point on whether constant returns to scale is at the 5% level of significance
Figures in parentheses are standard errors
Source Eslava et al (2004) dataset, Three digit Sector Intensity Division by Colombian El Banco de la Republica, authors estimations

Table 6a; Mean Plant Productivity Logarithmic Deviations by Trade & Factor Intensity & Size

		1980's			1990's		
		Trade Intensity					
Factor Intensity	Plant Size	Low	Medium	High	Low	Medium	High
Resources	Small	-0.08 (0.007) N=223	-0.20 (0.005) N=711	-0.12 (0.03) N=68	-0.18 (0.03) N=216	-0.24 (0.01) N=675	-0.24 (0.1) N=13
	Medium	0.02 (0.01) N=127	-0.02 (0.01) N=233	0.06 (0.005) N=390	-0.04 (0.03) N=120	-0.13 (0.005) N=236	-0.13 (0.02) N=9
	Large	0.20 (0.04) N=41	0.07 (0.01) N=82	0.18 (0.01) N=13	-0.01 (0.03) N=55	-0.03 (0.01) N=75	-0.08 (0.007) N=2
Labour	Small	-0.03 (0.01) N=309	-0.08 (0.01) N=694	0.08 (0.01) N=57	-0.11 (0.01) N=309	-0.06 (0.03) N=403	-0.16 (0.08) N=27
	Medium	-0.07 (0.02) N=117	-0.007 (0.01) N=218	0.18 (0.02) N=26	-0.17 (0.02) N=139	-0.04 (0.02) N=157	-0.32 (0.4) N=5
	Large	0.14 (0.01) N=57	0.13 (0.006) N=58	0.35 (0.08) N=5	-0.02 (0.06) N=31	0.04 (0.04) N=66	No Obs.
Capital	Small	-0.08 (0.03) N=115	0.005 (0.04) N=75	0.11 (0.02) N=698	No Obs.	0.14 (0.01) N=243	0.28 (0.01) N=557
	Medium	-0.05 (0.007) N=79	0.02 (0.02) N=16	0.24 (0.05) N=336	No Obs.	0.29 (0.01) N=141	0.22 (0.02) N=231
	Large	0.07 (0.02) N=17	0.25 (0.05) N=6	0.37 (0.02) N=136	No Obs.	0.77 (0.03) N=51	0.14 (0.02) N=84

Resource Intense sectors; 311 312 313 314 331 332 341 354 362 369 372 390
Labour Intense Sectors; 321 322 323 324 342 361
Capital Intense Sectors; 351 352 353 355 356 371 281 382 383 384 385
Plant Size; small <50 employees; medium <200 employees: big 200+ employees
N= Mean Number of Plants
Deviation; mean plant log difference for each group from all plant productivity for the respective period
Source Eslava et al Dataset, Banco de la Republica (intensity), DANE (apparent consumption), Authors estimates

Table 6b; Mean Plant level Productivity Fixed Effects
Logarithmic Deviations by Trade & Factor Intensity & Size From Period Mean

		1980's			**1990's**		
		Trade Intensity					
Factor Intensity	**Plant Size**	**Low**	**Medium**	**High**	**Low**	**Medium**	**High**
Resources	**Small**	-0.05 (0.004) N=223	-0.11 (0.004) N=711	-0.06 (0.02) N=68	-0.08 (0.01) N=216	-0.12 (0.007) N=675	-0.11 (0.06) N=13
	Medium	0.01 (0.007) N=127	-0.02 (0.005) N=233	0.02 (0.003) N=390	-0.02 (0.01) N=120	-0.07 (0.004) N=236	-0.07 (0.01) N=9
	Large	0.1 (0.03) N=41	0.02 (0.004) N=82	0.09 (0.001) N=13	-0.01 (0.02) N=55	-0.02 (0.005) N=75	-0.04 (0) N=2
Labour	**Small**	-0.02 (0.006) N=309	-0.04 (0.004) N=694	0.05 (0.01) N=57	-0.06 (0.007) N=309	-0.03 (0.01) N=403	-0.07 (0.06) N=27
	Medium	-0.05 (0.01) N=117	-0.006 (0.01) N=218	0.11 (0.01) N=26	-0.09 (0.01) N=139	-0.02 (0.02) N=157	-0.12 (0.24) N=5
	Large	0.08 (0.01) N=57	0.06 (0.004) N=58	0.2 (0.05) N=5	-0.01 (0.03) N=31	0.02 (0.01) N=66	No Obs.
Capital	**Small**	-0.05 (0.02) N=115	-0.006 (0.03) N=75	0.07 (0.01) N=698	No Obs.	0.07 (0.006) N=243	0.14 (0.008) N=557
	Medium	-0.04 (0.004) N=79	0.013 (0.02) N=16	0.14 (0.004) N=336	No Obs.	0.15 (0.007) N=141	0.11 (0.01) N=231
	Large	0.03 (0.02) N=17	0.12 (0.03) N=6	0.22 (0.007) N=136	No Obs.	0.40 (0.02) N=51	0.07 (0.01) N=84

Resource Intense sectors; 311 312 313 314 331 332 341 354 362 369 372 390
Labour Intense Sectors; 321 322 323 324 342 361
Capital Intense Sectors; 351 352 353 355 356 371 281 382 383 384 385
Plant Size; small <50 employees; medium <200 employees: big 200+ employees
N= Mean Number of Plants
Deviation; mean plant log difference for each group from all plant fixed effects for the respective period
Source Eslava et al Dataset, Banco de la Republica (intensity), DANE (apparent consumption), Authors estimates

Tables 6a and 6b show that the resource sectors saw a relative negative shift irrespective of plant size and trade intensity. Whilst during the 1980s large plants, particularly those in the trade sector, had productivity levels (and fixed effects) above the period mean, these all shifted to below mean in the nineties and the two plants that remained in the trade intense sector had the greatest negative deviation. This shift is in spite of a fall in plant numbers in all categories.

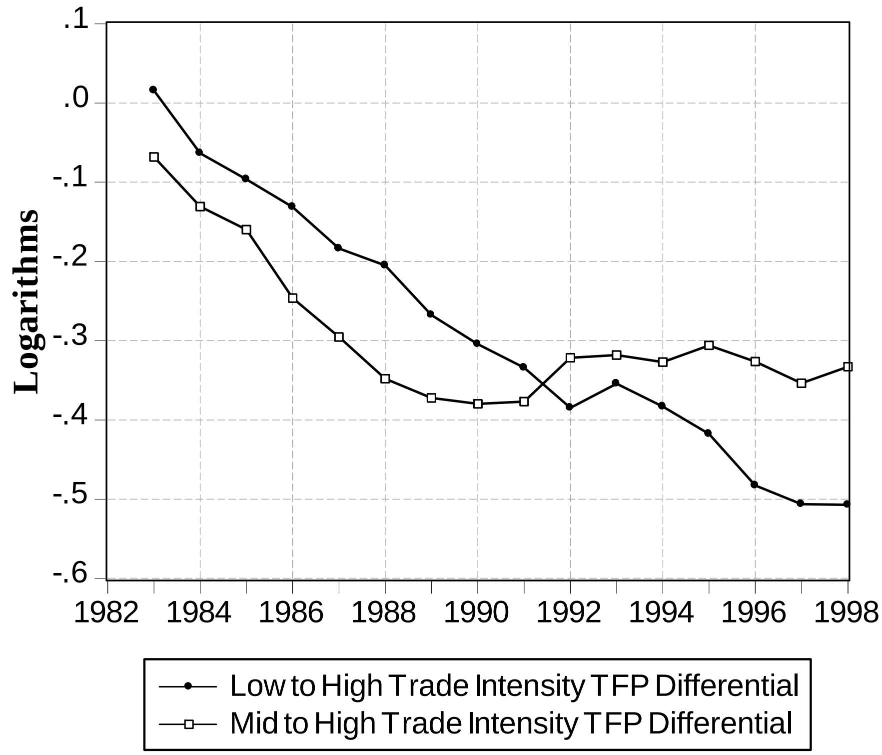
Labour intense plants saw a similar pattern, but the relative shift in the import intense plants was quite dramatic. Medium size trade intense plants saw a 0.18 positive deviation become a negative 0.32 deviation post liberalisation. All large trade intense labour plants either exited or saw a limited increase in trade intensity and as such shifted to the mid trade intense range where a positive deviation fell by two thirds. These relative losses were in spite of the strong within sector reallocation.

All 211 capital intense plants with low trade intensity in the 1980s either exited or saw an above average increase in trade intensity which shifted them to the mid or high range. We also see that even small medium trade intense plants have a positive deviation post reforms. The 872 capital intense plants with intensive trade all had positive deviations (especially the small plants). Yet the 56 plants in the resource and labour intense sectors with intensive trade all had negative deviations that were worse than the plants facing mid or low trade intensity.

The biggest change was in the large mid trade and capital intense plants. The mean *TFP* deviation grew from 0.25 to 0.77 logs (constant grew 0.12 to 0.4). Their productivity level now outstripped those in the high trade division, as did medium sized capital plants. The mid trade division absorbed a significant proportion of large capital plants as their trade intensity grew by less than the mean rate. This could indicate that the productivity gains made in the 1980s protected them from foreign competition or attracted FDI and that there were diminishing productivity returns to increased trade intensity above some optimum level.

Overall differences in productivity patterns are summarised in graphs 12 and 13. Graph 12 shows the steep growth in the differential between the mean weighted productivity in high trade intensive sectors and the other sectors during the 1980s. This is steeper than that between factor intensities. The difference in productivity continues into the 1990s with the low trade intense sectors, but it actually levels off with the medium trade intense sectors. This change in trend coincides with the full implementation of reforms and the rapid growth in FDI (graph A4 appendix)

Graph 12; Differentials in Mean weighted Productivity From High Trade Intense Sectors & Medium & Low Sectors



Source Eslava et al Dataset, Banco de la Republica (intensity), DANE (apparent consumption), Authors estimates

In graph 13 we plot mean *TFP* estimated by trade intensity. Those facing Low intensity trade saw 12% growth in the 1980's to which reallocation added 2.5%, This turned strikingly negative post liberalisation, decreasing by 21.5%, to which reallocation only off set 0.5%. The medium intense sectors matched the 12% growth, with reallocation adding 4%. Different to the other sectors though these sectors saw positive growth of 3% in the 1990s, to which reallocation added over half. Finally the high trade intense sectors saw a startling 44% growth in mean productivity in the 1980s, to which reallocation added 9.5%. This though became negative in the

1990s by 1.5%, with reallocation making very little difference. These figures are very much in line with those obtained dividing by factor intensity. That is, overall strong *TFP* growth in the latter years of ISI, followed by overall decline post liberalisation. We also see the positive differential of the most trade intense sectors attenuating.

7. Conclusions

The main aim of this paper was to analyse the impact of Colombian Liberalisation on the structure of manufacturing and within plant productivity levels. In achieving this aim we implemented methodological adaptations to current production function estimation techniques so as to make our *TFP* estimates more consistent. Our algorithm works quite nicely although some further experimentation with prices as IVs and comparisons with other techniques is still required.

The estimates from this methodology show, that post liberalisation mean within plant productivity fell. This fall was eventually offset by a reallocation of output to more productive plants within and across sectors. In comparison, within plant productivity actually rose during milder reforms to the ISI policy in the troubled 1980s.

The evidence suggests that the fall was caused by a combination of increased import competition, lower GNP growth, lower output-capital stock ratios and the response to electricity rationing. The first of these seem to have driven a large number of plants out of the formal sector as imports captured market share and weakened the relationship between GNP and domestic manufacturing output. This loss of market was not compensated by increased exports, growth in domestic demand or detained by increased plant capital intensity.

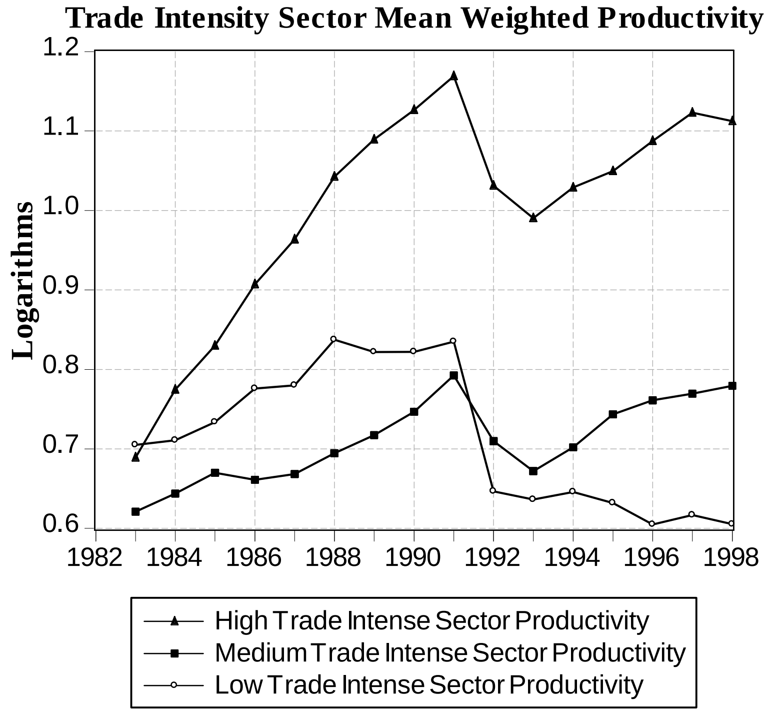
We see that high tariffs on low skilled labour intense plants were very effective. This was confirmed with their removal, which triggered a dramatic shift in output to larger plants producing less as output fell from 1991. Similar tariff and import changes in the resource intense sectors did not engender a sharp reallocation of activity and the drop in within plant productivity dominated.

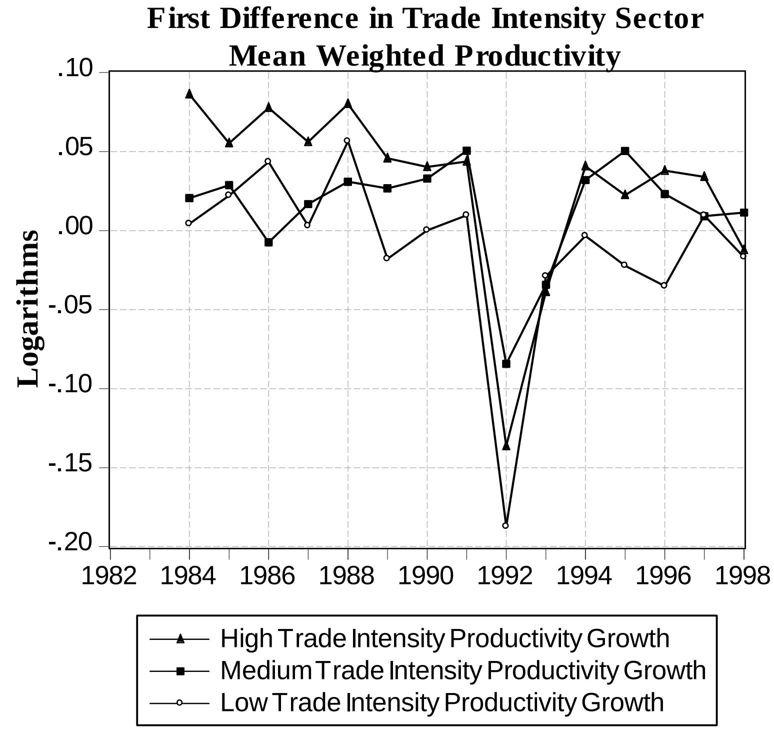
The relatively capital intense plants dominated the trade intense sectors pre and post reforms and they saw considerable structural change and reallocation with both the mild 1980s reforms and dramatic 1990s liberalisation. Even so these sectors saw a within plant productivity fall post reforms, which was just offset by reallocation.

Manufacturing wide plants facing the greatest trade intensity had lower productivity than those facing mid range trade intensity after the reforms. This was particularly noticeable amongst the capital intense plants. There is some evidence that the entry of greater FDI flows contributed to this shift. Overall the shift indicates that there was no simple monotonic relationship between trade intensity and productivity. We of course need to analysis the shift more deeply

Indeed this paper leaves a number of questions for subsequent analysis. In future work we hope to rigorously examine the link between trade intensity, FDI, capital levels and productivity; further examine distributional effects and reach conclusions on the direction of causality.

Graphs 13: Mean Weighted Productivity and First Difference by Trade Intensity





Source Eslava et al Dataset, Banco de la Republica (intensity), DANE (apparent consumption), Authors estimates

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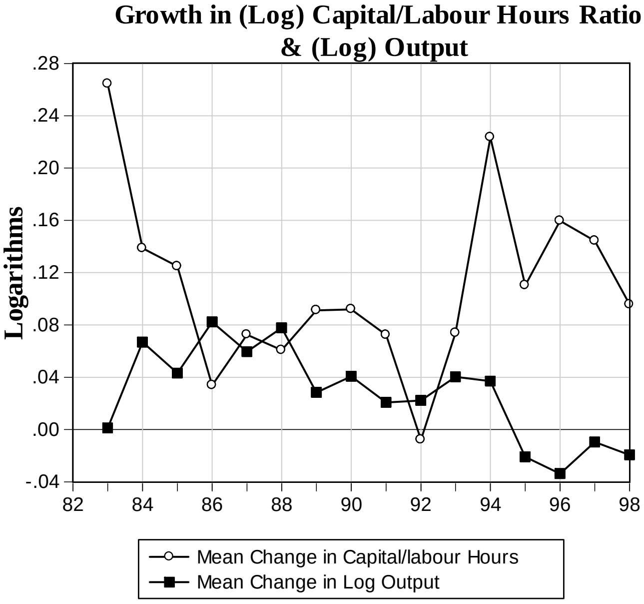
Appendix

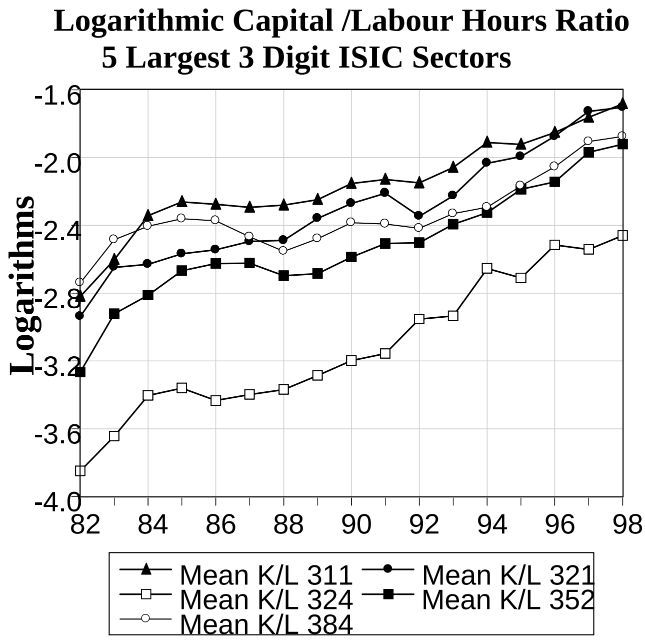
Table A1: (log) Capital Labour Hours Ratio Correlation with Components

Components	Correlations: Change in (log) Capital/Labour Hours Ratio	
	1982-1990	**1991-1998**
Change in Log Capital	0.82	0.76
Change in Log Labour Hours	-0.54	-0.62
Observations	42,422	38,780

Source Eslava et al (2004) Dataset, Author's Calculations

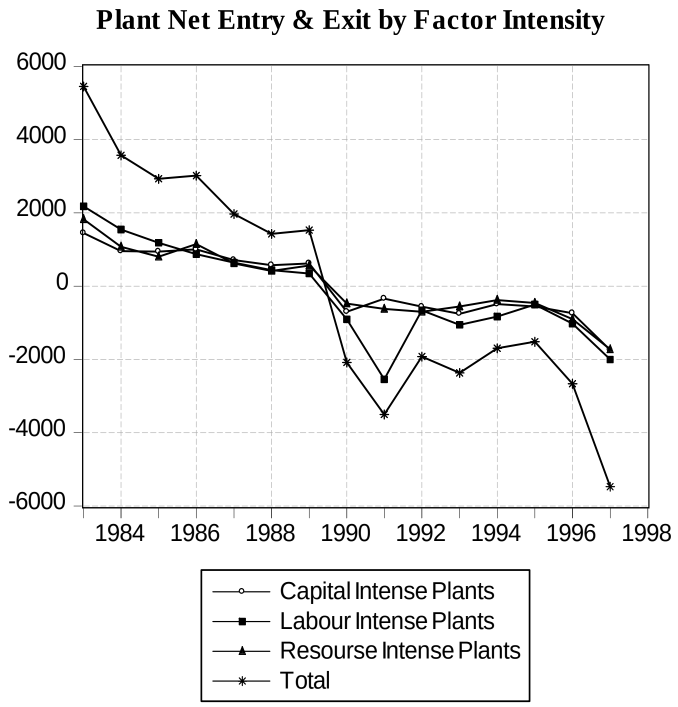
Graph A1; Growth in Capital Labour Hours & Output. & 5 Largest Sectors Capital Labour Hours Ratio

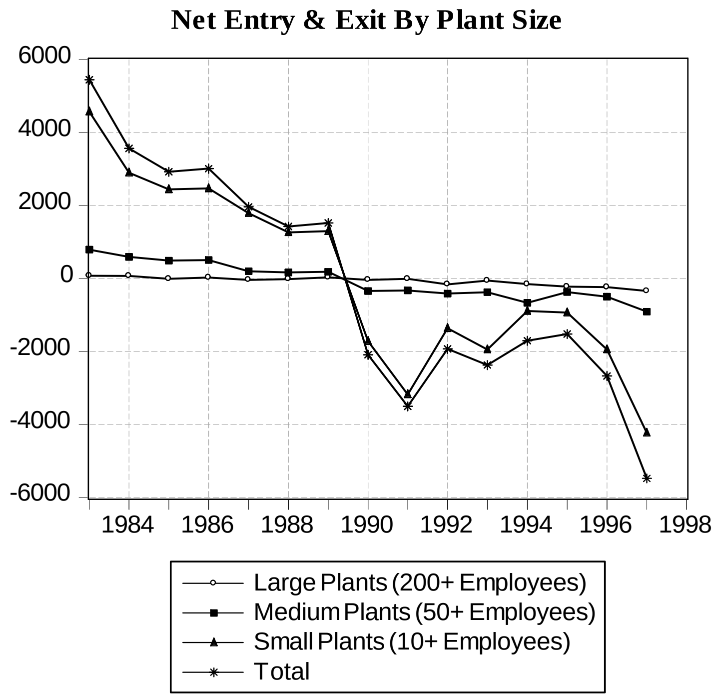




Source: Eslava et al(2004) dataset, Intensity defined by El Banco de la Republica; authors Calculations

Graphs A2; Descriptive Statistics: Plant Net Entry By Size & Factor Intensity

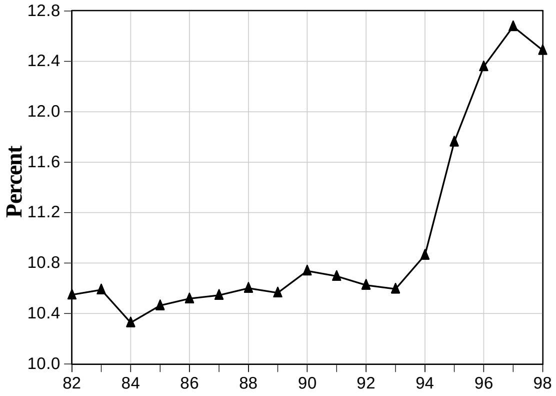




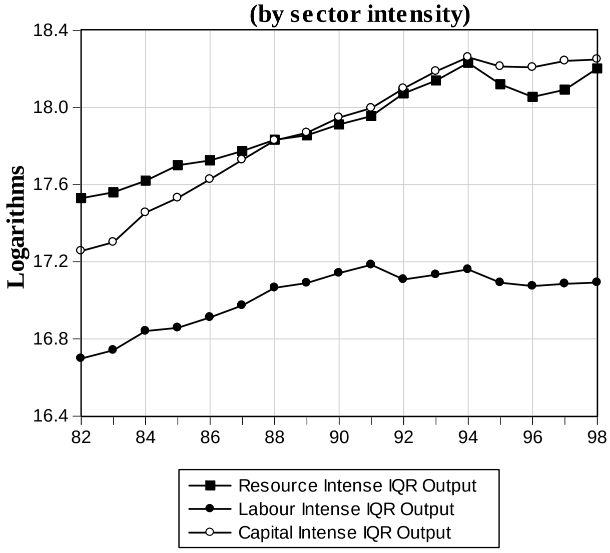
Source: Eslava et al(2004) dataset, Intensity defined by El Banco de la Republica; authors Calculations

Graphs A3; Output Difference between plant in & Out of Annual IQR & IQR Output by Factor Intensity

Percentage Difference Between Annual Total Output of Plants Outside Annual IQR & Plants Within Annual IQR



Output by Sector Factor Intensity: Output within Annual IQR of Output (by sector intensity)



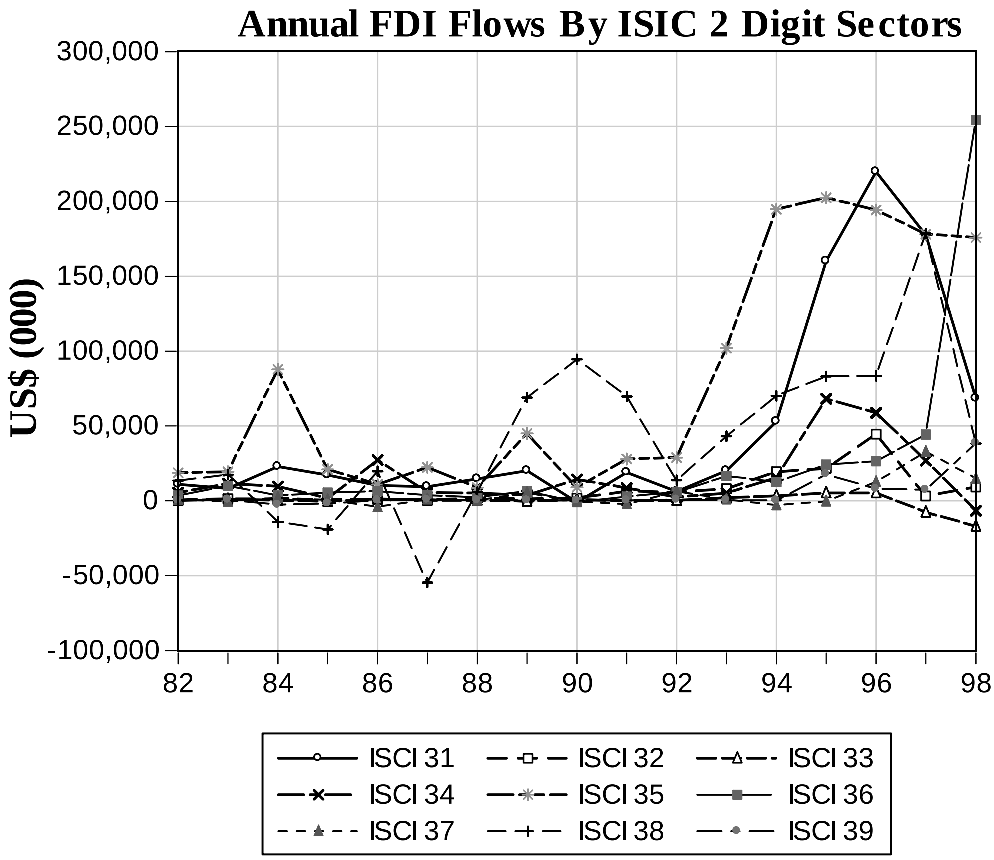
Source: Eslava et al(2004) dataset, Intensity defined by El Banco de la Republica; authors Calculations

Table A2: Percentage Share of FDI Flows

ISIC 2 digits Manufacturing Sectors		Period: 1982-90	Period: 1991-98
31	Food & Drink	11 (40.8)	18.6 (9.5)
32	Textiles, clothes & Footwear	1.34 (2.8)	4.4 (2.5)
33	Wood products & Furniture	0.05 (1.8)	-0.02 (1.4)
34	Paper, printing & Publishing	6.4 (22.9)	5 (4)
35	Chemicals & Petroleum Refineries	11 (83.3)	36.3 (11)
36	Pottery, china & Glass	3.3 (15)	10.2 (14)
37	Iron & Steel	-0.7 (4)	2 (3.5)
38	Fabricated metals & machinery	68.8 (163)	22 (14)
39	Other Manufactured products	-1.2 (3)	1.7 (2.2)
All	Total	11.1 (63.6)	11.1 (14)

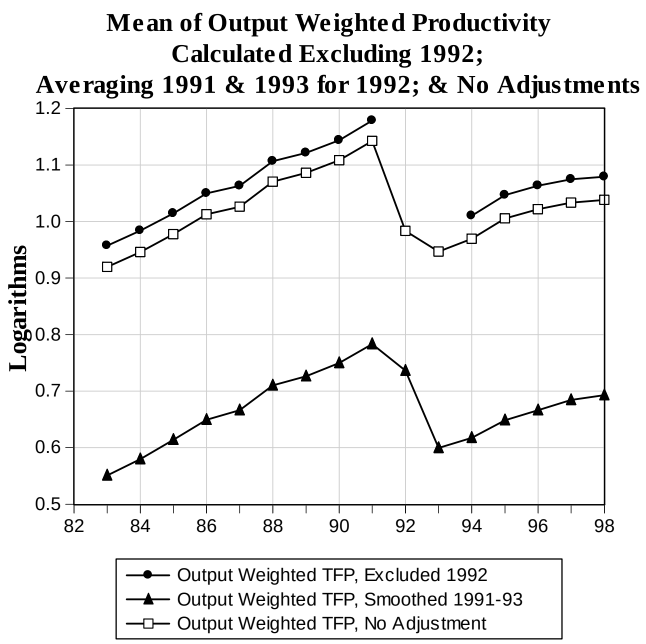
Data kindly provided by The Colombian Central Bank, Authors Calculations

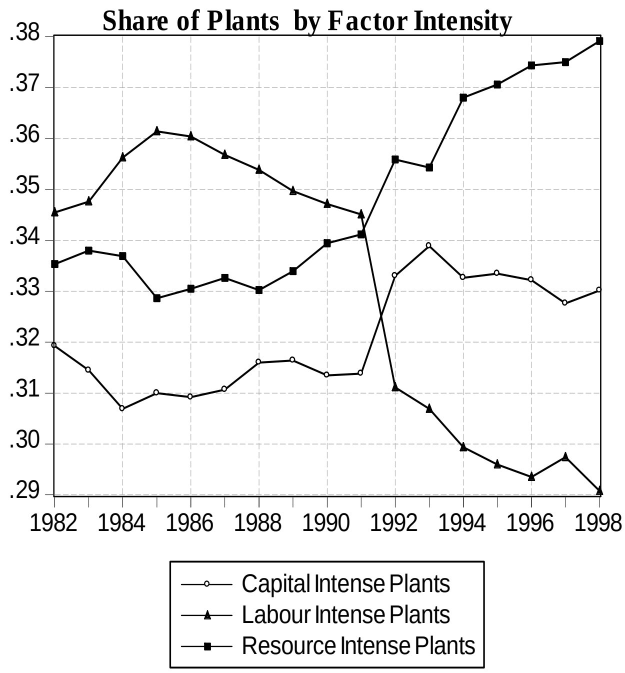
Graph A4: Annual FDI Flows by ISIC Sectors



Data kindly provided by The Colombian Central Bank, Authors Calculations

Graph A5; Weighted TFP Adjusting for 1992 & Plants by Factor Intensity





Source: Eslava et al(2004) dataset; authors Calculations

Table A3; Production Functions of the 5 Largest ISIC 3 Digit Sectors						
ISIC 3 Digit Sectors	Capital	Materials (proxy)	Labour	Energy	Constant Returns to Scale	Obs. Plants
311	0.085 (0.017)	0.796 (0.025)	0.094 (0.119)	0.026 (0.009)	Yes P=0.99	10,230 1,042
321	0.10 (0.029)	0.66 (0.04)	0.108 (0.027)	0.066 (0.018)	Yes P=0.051	4,257 452
324	0.099 (0.039)	0.69 (0.043)	0.107 (0.21)	0.079 (0.02)	Yes P=0.4	2,255 278
352	0.231 (0.066)	0.55 (0.083)	0.209 (0.04)	0.012 (0.019)	Yes P=0.89	3,186 294
384	0.179 (0.068)	0.36 (0.062)	0.34 (0.47)	0.096 (0.032)	Yes P=0.56	2,083 215

From an unbalanced sample of at least 5/17 observations per plant; 1,000 iterations per sector; materials proxy.
Figures in parentheses are standard errors
Source Eslava et al dataset, authors estimates

Table A4: Production Functions by Factor Intensity & Plant Size							
Factor Intensity [a]	Capital	Materials (proxy)	Labour	Energy	Constant return To scale	Obs. Plants	Net Plant Entry (%)
Resource [b]							
Small	0.04 (0.02)	0.72 (0.02)	0.17 (0.02)	0.06 (0.01)	Yes P=0.94	13,783 1,595	8%
Medium	0.07 (0.02)	0.71 (0.02)	0.25 (0.03)	0.06 (0.02)	No P=0.005	5,656 502	0.2%
Large	0.09 (0.04)	0.63 (0.05)	0.33 (0.04)	0.05 (0.02)	Yes P=0.09	1,966 163	-5%
Labour							
Small	0.1 (0.02)	0.58 (0.03)	0.1 (0.01)	0.06 (0.009)	No P=0	13,012 1,650	-20%
Medium	0.13 (0.03)	0.51 (0.05)	0.10 (0.03)	0.04 (0.01)	No P=0	4,923 464	-23%
Large	0.05 (0.08)	0.65 (0.1)	0.21 (0.05)	0.12 (0.05)	Yes P=0.74	1,612 135	-30%
Capital/skill							
Small	0.08 (0.01)	0.48 (0.02)	0.25 (0.04)	0.06 (0.03)		12,899 1,740	3.5%
Medium	0.07 (0.03)	0.48 (0.04)	0.25 (0.03)	0.13 (0.03)	Yes P=0.07	5,992 509	-15%
Large	0.14 (0.08)	0.53 (0.09)	0.15 (0.06)	0.04 (0.03)	No P=0.03	2,197 170	-20%

a: Relative factor intensity as set out by the Colombian Central Bank().
b: small plants have les than 50 employees, medium 50 to less than 200 and large 200 plus.
c: 1992 is excluded when period includes this year.
from an unbalanced sample of at least 5/17 observations per plant and 1000 iterations/Figures in parentheses are standard errors
Source Eslava et al dataset, authors estimates