INCENTIVES AND SOUTH AFRICA'S AUTOMOTIVE INDUSTRY PERFORMANCE: A SYSTEM DYNAMICS APPROACH

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Abstract: Investment in robotic automotive manufacturing and inherent electronics has played a pivotal role in the growth and competitiveness of the South African automotive industry. Government's offering of incentives was intended to lessen the cost of local industry's expensive, but necessary investment. Despite the growth, industry trade balance has been declining systematically. To explain the apparent contradiction in industry performance, a model of South Africa's automotive incentives – including the Productive Asset Allowance (PAA) and the Import-Export Complementation (IEC) – was developed. Model simulations reveal that, while the IEC had a significant effect on the industry trade balance, the role of the PAA in this regard is trivial. Ultimately, the study reveals that combining strictly investment incentives with other 'non-investment' incentives can have unintended consequences for the local automotive industry.

Keywords: Investment incentives, robotic automotive manufacturing, system dynamics, competitiveness

1. INTRODUCTION

For many countries that were late to develop and wished to improve their domestic manufacturing capacity, the question is no longer whether to give or not to give industry incentives, but how to structure such incentives to serve the national interest. The automotive industry is a key industry in South Africa and has been receiving government incentives for over a decade.

The aim of incentives is to support the industry to become globally competitive in the long term [1]. There was consensus that government had to motivate the local industry to invest in costly robotic manufacturing and electronics, as well as control systems engineering competencies that are of key importance, among others, to the competitiveness of automotive manufacturing.

Initially, the incentives were offered under an envelope programme: the Motor Industry Development Programme (MIDP). The programme has since been renamed the Automotive Production Development Programme (APDP). However, the effectiveness of the incentive dispensation in supporting industry competitiveness is being questioned. The increasing industry trade deficit that characterised the MIDP period is a particular concern.

Despite a steady increase in investment in state-of-the-art automated equipment, accompanied by a concomitant increase in vehicle production and exports, industry trade deficit increased from R12 billion in 1995 to R33 billion in 2006 [2]. The deteriorating trade deficit is threatening domestic vehicle production and the local sourcing of automotive components, contrary to intended objectives.

The MIDP policy framework was based on intuition and consensus among stakeholders. As such, some of its assumptions remain embedded in the mental models of its historical promoters, making it hard to uncover internal inconsistencies. The problem with intuitive models is that they cannot be scientifically assessed to allow objective improvement. Formalising intuitive mental models enhances mental model quality and increases the reliability of their simulations, which is a critical aspect of improving policy interventions [3].

This paper uses a system dynamics approach to formalise the Productive Asset Allowance (PAA) and Import-Export Complementation (IEC) incentives of the MIDP. The model is used to simulate the two incentives' medium-term effects on the industry trade balance under existing policy rules. The industry trade deficit has been identified as the main threat to the MIDP's success. Concluding remarks are based on the simulated model results.

2. INCENTIVES AND INDUSTRY PERFORMANCE

Industry incentives have been widely used as a tool to address industrial development in both developed and developing countries [4]. Offering incentives implicitly assumes a positive relationship between industry investment and investment incentives on the one hand, and between investment and industry performance on the other [5]. Conventional economic theory on the relationship between investment and investment incentives is often based on a neo-classical economic model of a profit-maximising firm. It is argued that such a firm will invest up to a point where revenue received from the sale of an additional product or service equates to the cost of the additional capital required for its production. The incentives offered reduce the cost of capital acquisition, hence motivating more investment, which holds other factors constant [6]. However, this literature is based on perfect market conditions that hardly exist in real-life situations. For this reason, its usefulness to practical policy makers is limited.

Hall and Jorgenson [7] pioneered earlier work on establishing the relationship between industry performance and the offer of incentives. They derived an investment function for a profit-maximising firm with user-cost of capital as one of the explanatory variables. They postulated that industry incentives reduce the user-cost of capital, thereby increasing investment and the subsequent expansion of productive activities. Nevertheless, Hall and Jorgenson's model is criticised for its failure to determine the rate of investment and relying on an ad hoc stock adjustment mechanism instead [8].

As an improvement on the model of Hall and Jorgenson, Tobin [9] proposed the q-theory model. In this theory, 'q' is defined as the ratio of the market value of capital to its replacement cost. According to Hayashi [10], the q-value motivates investment. The q-theory introduced the cost of installing new investment in the firm's optimisation decisions. Consequently, it captures the role of fiscal and non-fiscal industry incentives, as these have a direct effect on the cost of acquiring capital for investment regarding value to the firm derivable from it.

Again, a major limitation of Hall and Jorgenson's model and of Tobin's investment incentive theory is their inability to bridge the gap between theory and practice. The theoretical framework proposed does not account explicitly for demand constraints. Yet, in reality, what can be sold in a particular market has a significant influence on investment decisions in that location, which is sometimes more than the cost of capital. Moreover, strategic investment decisions may not necessarily be based on cost of capital per se. Strategic investment is common in the automotive industry. Global vehicle manufacturers locate production around the world, depending on which markets they plan to penetrate or protect in the long run. Theories on investment and investment incentives in the literature do not address these practical considerations.

Nonetheless, Hall and Jorgenson's investment model and Tobin's q-theory set the foundation for empirical work on establishing how incentives influence industry performance. Unfortunately, the number of empirical studies that have concluded that incentives positively influence industry performance and should therefore be encouraged [11, 12, 13] are as many as those against the use of industry incentives [14, 4]. Since findings on incentives and industry performance are mixed and inconclusive, each incentive offer has to be judged on its own merit, based on the unique location characteristics [15]. This applies to incentives offered to South Africa's automotive industry.

3. METHODOLOGY AND DATA SOURCES

Against the background of inconclusive relationships between industry incentives and industry performance, a system dynamics (SD) approach was used to model the effects of the PAA and IEC on the automotive industry trade balance. Basic econometrics was also used to establish the extent to which independent variables included in the model explained industry trade balance, which is the dependent variable of interest.

It is acknowledged that econometrics is the most used approach in industrial policy analysis. The methodology focuses on quantitative measurement and an analysis of economic phenomena. It is particularly useful in forecasting [16]. The forecasting power of econometrics and subsequent policy recommendations are based on a strong assumption that the previously observed phenomena will hold in future, which may not necessarily be the case. As such, the methodology is less appropriate for policy analysis that focuses on changing observed phenomena. In this case, the focus of analysis should be the understanding of dynamics pertaining to causality, rather than correlations or impact. SD methodology, based on operational thinking and control theory, provides a useful way to analyse policy interventions with the objective of changing performance. The SD approach allows the building of simulation models of complex situations using both quantitative and qualitative data so that such situations can be better understood and managed [17].

The MIDP incentive framework seems like a simple concept, yet its effects on industry dynamics are vast. The working of the MIDP incentives shows interrelationships between sector and industry variables without explicit cause and effect, which is a characteristic of a complex system.

The approach is based on the premise that the internal structure of any system determines the system's behaviour. Capturing feedback effects and non-linear relationships within a system and facilitating understanding of the relationship between the behaviour of the system and its underlying policy decision rules are at the core of the approach [18].

3.1 Data sources

Quantitative historical data was collected from the South African Department of Trade and Industry (thedti) and the National Association of Automotive Manufacturers of South Africa (NAAMSA).

Thedti carries out annual surveys to capture industry performance data as part of its monitoring mandate. Although part of this data is confidential, data relating to general trends in industry performance is published in the Department's annual publication *Current developments in automotive industry* and is available in the public domain. Thedti data is triangulated with other internal, but confidential data sources, thereby increasing its reliability.

NAAMSA is the national association of all local light, medium and heavy commercial vehicle manufacturers. It is also the representative organisation for franchise holders that market vehicles in South Africa. NAAMSA collects performance data from all its members. The data is published in the organisation's annual reports and is periodically disseminated to the public through press briefings. The NAAMSA data is more comprehensive and disaggregated, but can potentially be biased due to vested interests. NAAMSA data was compared with thedti data and, in cases of significant deviation between the two data sets, thedti data was preferred.

Thedti and NAAMSA data was supplemented by qualitative data collected from archive documents. Board of Tariffs and Trade (BTT) reports and government gazettes on the rationale for the introduction of the MIDP were specifically reviewed.

4. THE MIDP INCENTIVE MODEL

4.1 PAA model structure

The PAA is awarded according to the amount of the investment in productive assets. These should be assets that are directly applied during the conversion of raw material to finished goods. Such assets make up the largest proportion of industry investment, with a notably high cost associated with automated vehicle paint plants and robotic vehicle assembly stations replicated many times to carry out numerous consecutive operations. Significant investment in land, buildings, equipment and software for other major operations, such as marketing, finance, human resource administration, procurement and sales is excluded. To allow for this, total industry investment has to be multiplied by a fraction α to obtain the amount to be used for assets qualifying for the PAA, as shown by the following equation:

$$P_{AA}I_t = \alpha I_t \qquad (1)$$

Where:

$P_{AA}I_t$ = investment qualifying for the PAA in year t

I_t = total industry investment in year t

The PAA is awarded to claimants in the form of import rebate certificates. The use of these certificates is severely restricted. They can only be used by vehicle manufacturers/assemblers to import fully built-up vehicles. These imports are almost exclusively models that are not manufactured in the country. The underlying rationale is that this allows local vehicle manufacturers to rationalise production in the country to the one or two most viable models, while making a wider range of models available that are required in the local market. PAA certificates cannot be traded between vehicle manufacturers.

With regard to component manufacturers, only direct suppliers (Tier 1 suppliers) qualify for the PAA. Furthermore, the suppliers can only access PAA benefits if they provide government with an undertaking from vehicle manufacturers that they will only purchase components manufactured by qualifying assets. The relevant vehicle manufacturer commits itself to purchasing the PAA certificates generated at a fixed rate of 80% of the value. According to an explanation obtained from a government expert, these restrictive conditions were put in place because of the uncertainty of the potential drain from the pool of available duty rebates in addition to the existing IEC.

The value of the rebate is 20% of the amount of the investment that qualifies for the PAA. The value of rebates that a claimant can obtain from a particular qualifying investment can therefore be presented as follows:

$$P_{AA}RG = 0.2P_{AA}I_t \qquad (2)$$

Where:

$P_{AA}RG$ = PAA rebates generated in year t

0.2 = PAA benefit fraction as legislated.

Furthermore, the legislation stipulates that the value of the PAA rebates is spread over five years, starting in the year after capitalising the investment. The value of annual rebate certificates that can be generated is then as follows:

$$RCR = P_{AA}RG / 5 \quad (3)$$

Where:

RCR = the value of rebate certificate release per year

5 = the five-year period over which the PAA benefit is spread

The value of vehicles that can be imported in a particular year using PAA rebates depends on prevailing import duty and the value of PAA rebates issued in that particular year according to the following equation:

$$P_{AA}RI = RCR / IMPORTDUTY \quad (4)$$

Where:

$P_{AA}RI$ = the value of imports in the year under consideration using the PAA rebates

$IMPORTDUTY$ = the prevailing import duty rate in that year

To capture the feedback effect of the PAA, industry investment is made endogenous through the introduction of the investment rate variable. Therefore, annual industry investment is set to increase according to the following equation:

$$I_t = I_{t-1}(1 + I_{rate}) \quad (5)$$

Where:

I_{rate} = the annual industry investment growth rate

In addition to the value of rebatable imports introduced in (4) above, two other factors that determine the value of planned production are introduced in order to close the PAA incentive model loop, namely domestic market size by value and value of exports. This is done because it can be reasonably assumed that the value of investment will depend on the value of planned production.

The size of the domestic market is assessed by industry representatives to be the most important motivation for multinational vehicle manufacturers to invest in southern Africa [19]. Exports, on the other hand, augment the domestic market size, while imports, whether rebated or otherwise, reduce the effective domestic market. PAA rebatable imports add to the stock of industry imports into the country on which the industry does not pay duties. Given that the only way industry can benefit from the PAA incentive is through importing vehicles and offsetting duties payable using earned rebate certificates, firms will import until they have exhausted issued rebates [1].

To account for the difference that the PAA makes to production planning, a normal investment growth fraction variable is introduced. The normal investment growth rate is defined as the rate that would result from the influence of the size of the domestic market and export potential only, in the absence of PAA import duty rebates. To the extent that PAA rebatable imports also affect investment, actual investment growth fraction will differ from the normal growth fraction. The difference emanates from the planned production, which is postulated to be proportional to (domestic market + exports – PAA rebatable imports) / (domestic market + exports).

The effect of PAA rebatable imports on the planned value of production, which in turn affects actual investment growth fraction, constitutes a closed loop of the PAA incentive model. The feedback loop is implicitly nonlinear if the dynamics of the value of rebatable imports and the value of exports are considered. An increase in the value of rebatable imports relative to the value of exports reduces the rate of increase in investment through the actual investment growth fraction and vice versa.

The PAA model can be used to simulate values of rebatable imports under different scenarios. This can be done by specifying initial model values and rate of change values. Scenarios related to different values of the PAA benefit fraction, certificate spread period and import duty level can then be run.

However, in isolation, the PAA model underestimates the effect of rebatable imports on value of production planned, because the model does not consider additional rebatable imports generated under the IEC dispensation. The following section extends the PAA model to include the IEC contribution to the value of rebatable imports in the industry.

4.2 IEC incentive model

The IEC scheme is linked to the value of exports, but it also allows the import of vehicles using credits generated by the export of vehicles and components. The benefit is in the form of import rebate credit certificates (IRCCs), which are based on a proportion of exported local content.

In order to model the IEC scheme's contribution to the value of rebatable imports, one can start by assuming that the value of exports is determined by an export growth rate parameter, which is assumed to be exogenously determined. By obtaining an appropriate initial value, the following equation can be used to model industry exports per year:

$$E_t = E_{t-1}(1+\beta) \qquad (6)$$

Where:

E_t = total industry exports per annum in the year t

β = the export growth rate fraction

As IRCCs are based on a proportion of exported local content, the following additional equation is required:

$$ELC = ELCF * E_t \qquad (7)$$

Where:

ELC = exported value of local content

$ELCF$ = exported local content fraction

The IRCC value to be awarded to an exporting firm is calculated by discounting the value of exported local content at a predetermined rate that is scheduled to reduce over time as established in the initial MIDP framework. It is subject to adjustment in reviews. The schedule was introduced, in part, to encourage industry to grow its competitiveness.

The IRCC value generated is therefore not only a function of exported local content, but also of the exported local content beneficiation fraction (ELCBF), as determined for a particular year and reflected in the equation below:

$$IRCCVALUE = ELC * ELCBF \qquad (8)$$

Where:

$IRCCVALUE$ = the value of IRCCs generated in a year

$ELCBF$ = the export local content beneficiation fraction in the year under consideration

IRCCs are credits earned based on the value of exports used to offset duty payable on imports. The value of products that a company can import free of duty is equal to the value of the IRCCs that it can present against such imports. This value is independent of the import duty rates so no import duty factor, as in the case of the PAA in Equation (4), is required.

The value of imports paid for by IRCCs under the IEC incentive dispensation augment PAA-rebated imports. To account for the combined value of PAA- and IEC-funded imports on planned value of production, the PAA model was linked to the IEC model. A new variable, industry rebatable imports, was introduced. This is the sum of PAA-rebatable imports and IRCC-funded imports. A direct link between the value of industry rebatable imports and the value of planned production was then set up [1].

The model was extended to include the industry trade balance variable as the dependent variable of interest. This enabled simulation of the industry trade account, including sensitivity analyses of the trade balance account to changes in the PAA's policy rules and the IEC scheme.

In model simulations, the value of industry imports is specified as being endogenous, depending on the import decision, while exports are assumed to be dependent on annual export growth that can be estimated from historical data. It is assumed that the import decision is influenced by the value of the domestic market and the value of the rebatable imports at industry level. Before a firm within the industry can import, it has to estimate what value of imports the domestic market can absorb. After establishing the import absorption capacity of the domestic market, the firm will have to consider the almost mandatory import it has to undertake in order to make use of import rebates earned.

Hence, it is postulated that the value of the domestic market, together with the value of rebatable imports, determine the import decision. It is likely that industry imports will also increase as rebatable imports increase. If there is no commensurate increase in the value of the domestic market, the value of planned production will decrease. One way in which this manifests is that vehicle manufacturers and assemblers may not continue local supply of a certain type of component on model change, but rather import from a marginally lower cost source. In terms of the policy objectives, this would be an undesired outcome of incentive value oversupply. The impact of domestic market and rebatable imports on the imports growth fraction is dependent on the ratio of industry rebatable imports and the domestic market.

4.3 Adequacy of independent variables used in the simulation model

SD modelling protocol does not provide formal procedures for establishing the adequacy and relevancy of variables used in a model to explain a particular problem. The determination of the adequacy and relevancy of variables in the model is often a subjective process, which a researcher has to motivate.

To reduce subjectivity in determining the adequacy of independent variables in the model, trade balance was regressed against the size of the domestic market and industry investment. These key variables were not linear functions of the trade balance. Regression results showed that the size of the domestic market was statistically significant in determining industry trade balance as shown by the high t-value and low probability value. A unit increase in the size of the domestic market would increase trade balance by 0.74 units, which holds other factors constant.

Investment was not found to be statistically significant in determining industry trade balance. Its t-value of 0.346947 was too low and there was a high probability that its regression coefficient may not be different to zero. An R^2 value that indicated that the two variables explained more than 89% of the variation in the trade balance (Table 1) was important in establishing that the domestic market size and investment sufficiently explained changes in the trade balance.

Table 1: Regression results of trade balance, investment and domestic market size

Dependent variable = TBAR			
Variable	Coefficient	t-statistics	Prob.
INV	0.398	0.347	0.733
MKT	0.744	5.83	0.000
C	-19.7	-5.38	0.000
R-squared			0.896
Sum of squares explained by model			1833
Sum of squares explained by residual			212.1

4.4 Model validation

There is no rule of thumb in terms of the number of tests that should be carried out in order to establish the validity of a particular model. The onus is on the modeller to decide on the set of tests that would adequately create reasonable confidence in a model developed for a particular purpose. Given the applied nature of this research project, establishing model structural validity was not contentious because the qualitative and intuitive industry incentive framework was already in place and well documented. The researcher's role in this respect was to formalise the intuitive policy framework into an SD model by capturing the major source of dynamics relevant to the research problem and question.

In formalising existing policy frameworks, structural tests are continuously carried out in the sequential model-building process [20]. By the time the researcher develops a complete model on which behavioural tests can be performed the structural tests and validity would have been largely accomplished. Structural validity is evaluated through careful documentation of qualitative information on the policy framework and verifying the structure with stakeholders and experts at each stage of the model-building process. In this regard, the PAA guidelines and thedti archive documents on MIDP incentives provided well-documented reference notes on the structure of the PAA and IEC schemes.

Furthermore, before the scenario simulation, a base run of the model was performed to explore the extent to which the model replicated the reference behaviour of interest. Although the objective of SD modelling is not point prediction of system performance, but rather probing dynamics underlying a particular behaviour, it is important that an SD model can endogenously reproduce the reference mode of interest. Without replication of the reference mode, the model becomes irrelevant in providing insight into the problem's situation and cannot be useful. Richardson and Pugh [21] argue that if a model cannot reproduce its reference behaviour mode, it is invalid. The first behavioural test was to assess whether and to what extent the model reproduced the reference mode behaviour, which is the exponentially increasing industry trade deficit. The base run showed that the model could endogenously replicate the reference mode behaviour. Replication of the reference behaviour from an indigenous perspective indicated that the model could be useful in highlighting leverage variables or points of action that could influence the deteriorating industry trade balance.

5. EFFECTS OF THE PAA AND IEC ON THE AUTOMOTIVE INDUSTRY TRADE BALANCE

The generation process of PAA rebates and IEC IRCCs and their joint contribution to the industry trade balance account were translated into a set of stock and flow equations using Stella Version 9.0.1 modelling software. By providing initial values and model equation parameters, simulation of the effect of change in the two incentives' policy rules on the industry trade balance account trend was performed. The model equations used for the base run are presented in Appendix 1.

5.1 Effect of change of PAA policy rules on the industry trade balance

The PAA dispensation has two policy rule parameters that government can change. These rules have bearing on the industry trade balance account, namely the PAA benefit fraction and industry import duty. Model simulations showed that the effect of a change in the PAA benefit fraction on industry trade balance was marginal. Figure 1 shows how industry trade balance trends changed with PAA benefit fraction set at 20%, 30% and 40%. The lines practically coincide.

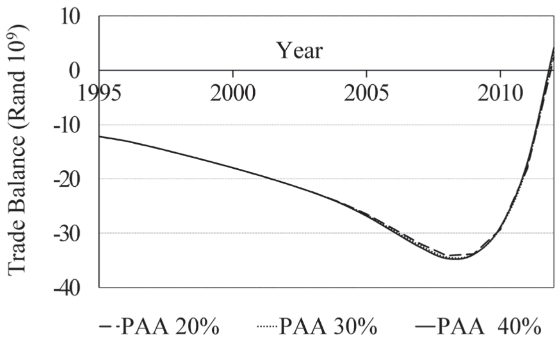

Figure 1: Effect of PAA benefit fraction on industry trade balance

The negligible effect of a change in PAA benefit fraction on the industry trade balance trend can be attributed to the relatively low value of PAA rebate certificates compared to the overall industry import value.

Similarly, the effect of a change in the import duty rate on industry trade balance trends was also trivial and comparable to that of the PAA benefit fraction. Model simulations showed that at an import duty of 20% and 30%, the impact of import duty on industry trade was almost synonymous to that of a change in the PAA benefit fraction. Even the further lowering of the import duty to 10% did not change the trade deficit trajectory (Figure 2).

Within the assumptions of the model, import duty adjustment, just like the PAA benefit fraction, could not be used to influence industry trade balance under the PAA incentive dispensation. It should be noted, though, that the duty rate of 10% is sufficiently low that it could cause manufacturers to exit the industry and continue their commercial activities by only importing vehicles and components. This option was not included in the model, but could readily be included in an extension of it.

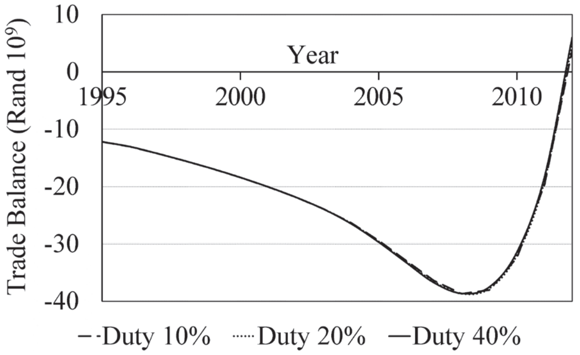

Figure 2: Effect of import duties on industry trade balance

5.2 *Effect of change in IEC policy decisions on the industry trade balance*

The IEC dispensation has one effective policy lever under the control of policy makers: ELCBF. Setting the ELCBF at 0% was equivalent to complete neutralisation of the incentive, while setting the benefit fraction at 100% benefits industry equivalent to the full value of exports. Since there were no indications to reduce the benefit fraction below 50% at the time of research, the trade balance sensitivity to ELCBF was done by setting the fraction at 50%, 80% and 100%. Simulation results showed that the model was very sensitive to the ELCBF. With the fraction set at 50%, there was the minimum deterioration in the industry trade balance relative to the 1995 status before the deficit started to decline. The increase in trade deficit, before the decline set in was more pronounced at 100% benefit fraction when compared to 80% (Figure 3). Generally, the lower the ELCBF, the less is the decline in industry trade balance.

It should be noted, however, that the analysis above was based on the effect of ELCBF on the supply of IRCCs in value terms. An increase in ELCBF may also have a ‘demand effect’ in terms of motivating the industry to export products with higher local content. In order to do so, industry has to increase its local sourcing of products. Local sourcing of products offsets potential imports; hence it has a positive effect on the industry trade balance. The opposite results of the supply and demand side effects on the industry trade balance may question the soundness of the trade balance trend captured in Figure 3. However, given the limited capacity of the domestic component manufacturing sector to meet vehicle assemblers’ component supply requirements, even if there was intention to increase local sourcing, the increase would not be drastic.

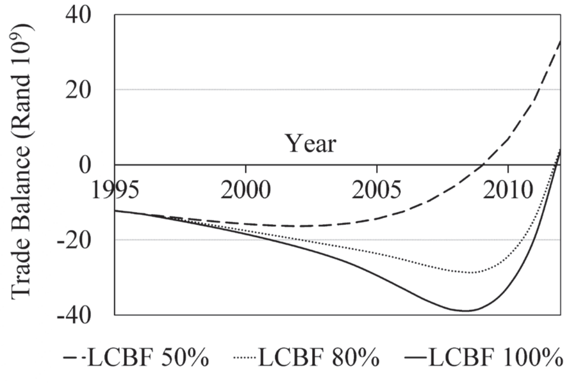

Figure 3: Effect of exported local content benefit fraction on industry trade balance

From this reasoning and from on-going observation of industry activity, it was judged that the effect of change in the ELCBF was more likely to increase IRCC supply than increase local component sourcing. By implication, model simulations pointed to the fact that the deteriorating industry trade deficit witnessed under the MIDP period could have been mitigated effectively by adjusting IEC ELCBF, unlike the limited effectiveness of adjusting PAA parameters.

6. INSIGHTS

The IEC, rather than the PAA incentive, was the major contributor to the industry trade deficit. Adjustment of PAA benefit fraction and import duty rate would have had little effect on the industry trade balance trend. The IEC, on the other hand, provided a high leverage policy to potentially influence the industry trade balance account. The deteriorating industry trade deficit could be influenced significantly by adjusting policy rules pertaining to the IEC incentive dispensation.

In general, this research and modelling indicates that production, rather than investment-based incentives, are effective in influencing South Africa's automotive industry performance in terms of industry trade balance. Without negating the need to provide incentives for investment in high-technology robotic manufacturing and accompanying electronics and control systems engineering competences, the study reveals that combining such incentives with other 'non-investment' incentives may have unintended consequences, a phenomenon SD literature refers to as policy resistance. Persistent trade deficit was not anticipated in the process of coming up with an incentive package for the South African automotive industry. This finding can be useful in the future structuring of new automotive incentives for South Africa and against the background of the country's desire to maximise the socio-economic benefits of local manufacturing activities. Potential synergies and trade-offs of a combination of industry incentives have to be taken into account to minimise the likelihood of policy resistance.

It should be noted that the modelling process, as explained in this paper, has limitations, even though they are not significant enough to change the paper's contributions. Firstly, the model was not accurate in point prediction of trade balance over time, but it could replicate the general trade balance trend. This weakness is typical of SD modelling. It tends to emphasise the overall trend replication of a research aspect of interest rather than point prediction. Secondly, exogenously determined rates of change based on historical data were used in model simulation. These rates were assumed to hold in future, which may not necessarily be the case. In terms of future research on the topic, it is suggested that some of the assumed exogenous rates are made endogenous through a careful process analysis of what drives these rates in reality. This will make the model more robust.

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8. APPENDIX 1

8.1 Equations for the PAA-IEC model base-run

Domestic_market(t) = Domestic_market(t - dt) + (Market_growth) ∗ dtINIT Domestic_market = 33.6 {Rand billion} (1)

Inflows:

Market_growth = Domestic_market ∗ Market_growth_fraction (2)

Exports(t) = Exports(t - dt) + (Exporting) ∗ dtINIT Exports = 4.2 {Rand billion} (3)

Inflows:

Exporting = Exports ∗ Export_growth_fraction {Rand billion} (4)

Imports(t) = Imports(t - dt) + (Importing) ∗ dtINIT Imports = 16.4 {Rand billion} (5)

Inflows:

Importing = Imports ∗ Import_growth_fraction (6)

Investment(t) = Investment(t - dt) + (Investing) ∗ dtINIT Investment = 0.85 {Rand billion} (7)

Inflows:

Investing = Investment ∗ Actual_growth_fraction {Rand billion} (8)

IRCCs(t) = IRCCs(t - dt) + (IRCC_generation - IRCC_release) ∗ dtINIT IRCCs = 0 {Rand billion} (9)

TRANSIT TIME = varies (10)

INFLOW LIMIT = INFINITE (11)

CAPACITY = INFINITE (12)

Inflows:

IRCCgeneration = Local_content_benefit_fraction ∗ Exported_local_content {Rand billion} (13)

Outflows:

IRCC_release = CONVEYOR OUTFLOW (14)

TRANSIT TIME = IRCC_release_delay {Rand billion} (15)

PAA_Rebates[Annual_Certificate](t) = PAA_Rebates[Annual_Certificate](t - dt) + (Rebate_generation[Annual_Certificate] - Rebate_certificate_release[Annual_Certificate]) ∗ dtINIT PAA_Rebates[Annual_Certificate] = 0 {Rand billion} (16)

Inflows:

Rebate_generation[Annual_Certificate] = Qualifying_investment ∗ Benefit_fraction / Certificate_spread {Rand billion} (17)

Outflows:

Rebate_certificate_release[1] = CONVEYOR OUTFLOW (18)

TRANSIT TIME = Rebate_Certificate_delay[1] (19)

Rebate_certificate_release[2] = CONVEYOR OUTFLOW (20)

TRANSIT TIME = Rebate_Certificate_delay[2] (21)

Rebate_certificate_release[3] = CONVEYOR OUTFLOW (22)

TRANSIT TIME = Rebate_Certificate_delay[3] (23)

Rebate_certificate_release[4] = CONVEYOR OUTFLOW (24)

TRANSIT TIME = Rebate_Certificate_delay[4] (25)

Rebate_certificate_release[5] = CONVEYOR OUTFLOW (26)

TRANSIT TIME = Rebate_Certificate_delay[5] {Rand billion} (27)

Actual_growth_fraction = Normal_growth_fraction * production_potential_factor (28)

Annual_certificate_release = ARRAYSUM(Rebate_certificate_release[*]){Rand billion} (29)

Benefit_fraction = 0 + STEP(0.2, 2001) (30)

Certificate_spread = 5 (31)

Exported_local_content = Exports * Exported_local_content_fraction {Rand billion} (32)

Exported_local_content_fraction = 0.7 (33)

Export_growth_fraction = CGROWTH(27) (34)

Import_duty = 0.3 (35)

Import_growth_fraction = (CGROWTH(12) * Impact_of_rebatable_imports_and_domestic_market_on_imports) (36)

Industry_rebatable_imports = IRCC_rebatable_imports + PAA_rebatable_imports {Rand billion} (37)

Industry_trade_balance = Exports - Imports {Rand billion} (38)

IRCC_rebatable_imports = IRCC_release * 1 {Rand billion} (39)

IRCC_release_delay = 1 (40)

Local_content_benefit_fraction = 0.9 (41)

Market_growth_fraction = CGROWTH(9) (42)

Normal_growth_fraction = 0.15 (43)

PAA_rebatable_imports = Annual_certificate_release / Import_duty {Rand billion} (44)

Production_potential_factor = (Domestic_market + Exports - Industry_rebatable_imports)/ (Domestic_market + Exports) (45)

Qualifying_investment = Investment * Qualifying_investment_fraction {Rand billion} (46)

Qualifying_investment_fraction = 0.8 (47)

Rebate_Certificate_delay[1] = 1 (48)

Rebate_Certificate_delay[2] = 2 (49)

Rebate_Certificate_delay[3] = 3 (50)

Rebate_Certificate_delay[4] = 4 (51)

Rebate_Certificate_delay[5] = 5 (52)

Import decision

Impact_of_rebatable_imports_and_domestic_market_on_imports = GRAPH (Industry_rebatable_imports/Domestic_market) (0.00, 1.00), (0.04, 1.00), (0.08, 1.20), (0.12, 1.31), (0.16, 1.43), (0.2, 1.51), (0.24, 1.61), (0.28, 1.71), (0.32, 1.76), (0.36, 1.76), (0.4, 1.75), (0.44, 1.70), (0.48, 1.60), (0.52, 1.55), (0.56, 1.50), (0.6, 1.46), (0.64, 1.41), (0.68, 1.36), (0.72, 1.35), (0.76, 1.32), (0.8, 1.30), (0.84, 1.29), (0.88, 1.29), (0.92, 1.29), (0.96, 1.29), (1.00, 1.00) (53)