Modeling effects of incentives for industry competitiveness using a system dynamics approach

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Abstract

Investment in state of the art machinery and tooling and in R&D is widely seen as a prerequisite for achieving industry competitiveness in the long term. Investment-based incentives that countries provide for these inputs are perceived as a way of supporting industry competitiveness. Despite this being a global phenomenon, there is no formal process to guide the offer of these incentives. The process of designing such incentives is often based on internalized judgment rather than on formal models making it difficult to assess such interventions objectively and to improve on them. Specific to South Africa, the offer of incentives to the automotive industry to support its competitiveness has had mixed results. In particular, investment in R&D has remained minimal. The paper presents a system dynamics model as a proposed instrument in formalizing the offer of incentives, applied to the South African government's offer of incentives to the automotive manufacturing sector. The model was developed from qualitative and quantitative information on how the incentives had been structured. Simulations of the model reveal that the incentives model, as a stand alone intervention, had a significant and positive effect on industry investment, but had no specific policy lever to direct investment into R&D and subsequent innovative activities. By this measure, the incentives model has not been a strong policy framework for supporting long-term industry competitiveness.

Keywords: *Automotive manufacturing incentives, R&D, system dynamics*

I. INTRODUCTION

In an effort to support competitiveness in domestic industries, many late developing countries offer incentives based on investment in machinery and tooling, and local R&D. The configuration of the incentives is often based on internalized judgment rather than on formal models, making it difficult to assess such interventions objectively and to improve on them. Formalization of such policy interventions makes explicit the factors underlying performance and can reveal high leverage policy options available to policy makers to influence performance. The paper was aimed at showing how formalization of incentives policy for competitiveness can reveal insights useful in understanding target industry performance and how it can guide subsequent improvement of such policy interventions. This was done using the case of South Africa's automotive industry and against the background of mixed performance of the industry regarding competitiveness.

Like in many developing countries, South Africa's adoption of an outward-looking industrial development policy strategy after its 1994 democratic transition was motivated, in part, by the desire to detach domestic industry performance from national economic growth [3]. It was acknowledged that the domestic market was not able to support sufficiently high production volumes that could allow efficient and competitive domestic production. Given the emphasis put on exports and foreign investment to drive national growth, international competitiveness became an important component of overall national development strategy. South Africa's policy makers hoped to emulate the successful interventions of some East Asian governments that had achieved high economic growth rates through exporting [7]. In 1995, the South African government launched a Motor Industry Development Program (MIDP) aimed at establishing a competitive industry, both locally and globally. Under the program, government provided the industry with import duty rebates based on local content exported and with a duty free allowance. The MIDP replaced a series of protection measures and local content requirements that had previously characterized the industry [3]. The main objectives of the MIDP were to increase competitiveness of the industry, encourage industry growth through export, stabilize employment levels, improve the industry's trade balance and to make vehicles more affordable in the domestic market [2]. In 2000, government introduced an investment incentive for the industry, the Productive Asset Allowance (PAA). The PAA was intended to support further efforts to make the domestic industry competitive in the long term. Investment qualifying for the PAA was widely defined to include capitalized R&D expenditure [17].

Despite government's offer of substantial incentives to the local automotive manufacturing industry, investment in R&D remained minimal. For the first decade of the incentives offer, 1995-2004, R&D investment as a proportion of total industry investment was less than 10% on average (Table 1).

Table 1: Investment expenditure by South African vehicle manufacturers

Year	**Total Investment (Rm)**[1]	**Investment in support infrastructure (incl. R&D) as a % of total the investment**	**Investment in plant, machinery and tooling -as a % of total the investment**
1995	847	9.2	86.6
1996	1,171	11.1	85.0
1997	1,265	8.8	81.0
1998	1,342	10.4	85.2
1999	1,511	7.6	87.0
2000	1,562	9.0	83.9
2001	2,078	11.8	86.6
2002	2,726	9.6	84.8
2003	2,325	8.3	85.5
2004	3,577	10.1	86.9

(Department of Trade and Industry, 2004 and NAAMSA Annual Report 2001/2006, p.15)

The low level of R&D in the automotive manufacturing industry was corroborated by findings of the South African Innovation survey of 2001. The survey found that South Africa's R&D expenditure as percentage of sales in the manufacturing of machinery and equipment to be 0.8% [28].

The nature of investment realised under the MIDP was an issue of concern in as far as the industry competitiveness objective was concerned since R&D investment, as opposed to capital investment, is associated with improved industry competitiveness [37]. Investment in plant, machinery and tooling is important in the realisation of short to medium term profitability of firms, but in the long run it is the R&D investment and the subsequent potential to innovate that is likely to determine industry competitiveness [8], [29], [20], [18].

Using a system dynamics approach, the paper presents a system dynamics model as a proposed instrument in formalizing the offer of incentives, applied to the South African government's offer of incentives to the automotive manufacturing sector. The model was developed from qualitative and quantitative information on how the incentives had been structured. It was used to test how changes in the incentive policy rules affect industry performance dynamics pertaining to progress towards competitiveness.

II. Industry competitiveness and R&D Investment: Literature review

R&D can be defined as a formal improvement-driven undertaking to discover new knowledge about products, processes and services. It comprises of the bulk of creative systematic activities undertaken to increase stock of knowledge and the subsequent use of this knowledge to devise new application [9]. According to Zhouying [42], R&D entails developing of technologies that can be commercialised under independent intellectual property rights. R&D is seen as the foundation of technology progress and sustainable competitiveness in the modern era [10], [40], [22], [21], [34].

Competitiveness, on the other hand, refers to the ability of a firm or industry to increase in size, market share and profitability. Quoting the US Presidential Commission on Industrial Competitiveness, Clark and Guy [5] define competitiveness as "the degree to which it (a nation) can, under free and fair market conditions, produce goods and services that meet the test of international markets while simultaneously maintaining and expanding the real income of citizens".

The contemporary thinking is that the link between R&D and competitiveness is via its effect on technological development and subsequent innovation. Innovation, technological advances and country competitive advantage happen to be connected by complex multidimensional relationships [21]. It is reasoned that competitiveness depends on average production costs. Production costs are a function of price and non-price factors, some of which are R&D capabilities and the ability to adopt and use new technologies. Sustainable competitiveness depends on the ability of a country or industry to offer comparable products to its competitors at lower prices on an open market. This requires that a country or industry is able to lower its production costs without sacrificing quality. Technology innovation offers one of the most practical ways to reduce production costs while at the same time maintaining or even increasing product quality. R&D investment has a powerful positive correlation with industrial profitability, product quality, and return on investment, hence overall competitiveness [24], [41]. R&D activities generate knowledge, which is a factor of production, as such, an indirect input in the neo-classical production function [29]. Therefore, there is general agreement that countries seeking to enhance their international competitiveness, have to engage in domestic R&D and subsequent innovative activities [19], [40].

Nonetheless, the link between R&D effort, innovation, technical progress and competitiveness has to be qualified; it is not straightforward and is characterised by time lags. For competitiveness to be realised, R&D generated knowledge has to be adopted and commercialised by industry; otherwise, the knowledge remains valueless. R&D is an input in the long process of achieving competitiveness. Like any other input in a chain of interrelated activities of a system, the relationship between input and output may be hard to establish. One has to consider time lags and control for other "competitiveness-determining" factors that simultaneously change with R&D efforts over time.

Another challenge in the R&D and competitiveness analysis relates to measuring the effectiveness of R&D. Frankema and Lindblad [10] point out that "Figures on R&D activities and numbers of people employed in R&D activities, the commonly used indicators of R&D activity, merely inform us about the scope of efforts and financial commitments but do not offer insight into the effectiveness of R&D efforts". The R&D success rate is dependent on a range of intermediary factors like knowledge management, technology absorptive capacity of the environment, and other soft technological variables. Zhouying [42] claims that soft technological factors that relate to the emergence of new business technologies and cultures, such as modern management techniques, venture capital, virtual technology, incubators, etc. constitute soft technology that provides an environment for innovation and effective application of technologies, hence attainment of competitiveness. Because of the complex relationship between R&D investment and competitiveness, governments ought to carefully develop evaluation criteria for R&D sponsored programmes in order to direct the behaviour of recipient firms [9].

Notwithstanding concerns on R&D effort and competitiveness, there is no doubt that new knowledge drives innovation and new knowledge is rooted in R&D activities. Innovation and technological capability are important assets for any country or industry in getting a competitive edge over its rivals in free and contestable markets. Achieving competitiveness is closely related to and intertwined with technology progress. Stumpf & Vermaak [37] emphasise that global competitiveness is inseparably linked to productivity improvement and technology upgrade. Carayannis & Roy [4] on the other hand postulate that a firm's long-term competitiveness is directly proportional to its speed and acceleration of innovation. Global technology improvement has led to a decrease in product life cycles. Facilities, equipment and worker skills are rendered obsolete long before their useful lives have been realised [24]. In order to remain competitive, firms have to innovate continuously and need to ensure that they realise a positive return to innovation-related investment over shorter periods.

Firm expenditure on R&D and innovation activities is a long-term, high-risk form of investment but one that is necessary for industrial survival and profitable growth [24], [30]. Because R&D and subsequent innovative activities often requires substantial investment with high risk, governments have to play a key role in encouraging and facilitating this type of investment [10]. One of the ways governments to do this is through the offer of industry incentives.

The beginning of the 21 century has also seen Multi National Corporations (MNCs) increasingly globalising their R&D activities by taking advantage of governments' support mechanisms [12], [15]. The phenomenon has motivated more developing countries to introduce incentives and institutional arrangements that can attract investment, including R&D activities, in local economies. This is done with the expectation that government R&D incentives will have a positive effect on a country's innovation effort and subsequently on its competitiveness [13].

Although empirical evidence on the effect of government incentives and private sector investment in R&D is still inconclusive [16], for the South African automotive industry, with a location disadvantage, it was unlikely that the country could attract significant investment in R&D without some sort of compensatory incentives. Against this background, the South African government introduced automotive incentives for the local industry. The PAA in particular targeted state-of-art asset investment, R&D and capitalised expenditure on technical expertise. The expectation was that the incentives would encourage, fairly equally, all the forms of investment and ultimately contribute towards efforts to make the domestic industry competitive in the long term. Ten years after the commencement of the incentives most of the investment realised was in form of plant, machinery and equipment.

The ineffectiveness of South Africa's automotive manufacturing incentives to direct investment in R&D and subsequent innovative activities necessitated a review of the automotive industry incentive model. For this to be done rigorously, however, a formal model had to exist. Like many policies in developing countries, the MIDP policy framework was based on judgment or intuition and on consensus among stakeholders. Its assumptions remained embedded in the mental models of its historical promoters, making it hard to discern internal inconsistencies. The problem with intuitive models is that they cannot be assessed scientifically to allow objective analysis and improvement [36], [11]. In order to investigate how a change in incentive policy rules would affect industry performance dynamics in respect of the industry's competitiveness objective, a system dynamics model of the industry incentives was developed. Formalizing of intuitive mental models has a potential to expose flaws in policy conception and can reveal the effectiveness of policy levers in the model structure [36]. As a result, model formalization enhances models' quality and increases the reliability of their simulations, an aspect critically important for improvement of policy intervention [32]. The developed model provided a formal means to test how policy decisions on the MIDP incentives could affect industry competitiveness in the long term.

III. METHODOLOGY AND DATA

In the formalization of the competitiveness incentives for South Africa's automotive manufacturing industry, a system dynamics (SD) approach was used. The choice of system dynamics was motivated, in part, by the complexity of industry performance dynamics and by the need to account for feedback effects of any industry intervention.

The workings of the MIDP incentives exhibit interrelationships between industry sectors and industry performance variables without explicit cause and effect characteristic of a complex system. External inputs to the industry, such as incentives, cannot be directly mapped to realised outcomes because of the complex interrelationships within the industry. Vennix [38] contends that the system dynamics approach is more suited to capture such relationships and feedback effects within a set of interrelated activities and processes. According to Barlas [1] and Randers [31] the system dynamics approach is more applicable to policy problems where the dynamics have to do with the internal structure of the system as it has a potential to generate understanding of how a complex system is structured and can influence the effectiveness of policy input.

It was further acknowledged that policy work is often too complicated to be reduced to definite natural science laws and econometric models [35]. Economic policies pursued by different countries are unique and are a function of a set of circumstances peculiar to a country. They are intended to meet sets of objectives that cannot be reduced into functions to be optimised. Moreover, world circumstances are always changing, therefore, replication and generalisation of particular research findings, the two strongest arguments for most dynamic optimisation and pure econometric approaches, become less achievable. The key question(s) to be answered by the study were 'what if' questions, that is, what would happen to industry performance in relation to the competitiveness objective if the incentive policy rules were changed. System dynamics simulation models are more suited to answer such "what if" questions [33].

System dynamics as a methodology is grounded in control theory and theory of nonlinear dynamics [36]. The approach provides a means to capture complex relationships and feedback effects within a set of interrelated activities and processes that often characterize policy models [38]. It allows simulation of model performance under different policy rules giving some indication into potential outcomes of particular policy decisions before their implementation. Its presentation has a user-friendly interface that encourages users in practice to internalize the logic behind the model. In addition, the approach allows the use of quantitative and qualitative data; hence, it is not limited in its use when quantitative data is unavailable. Specialized software in system dynamics modeling allows scenario simulations, in fairly easy and understandable steps, an aspect that is important in practice and in applied research. For this project Stella software version 9.0.2 was used, as developed by the company isee systems (formerly High Performance Systems - www.iseesystems.com).

Quantitative industry performance data for estimation of model parameters and rates of change was collected from the Department of Trade and Industry, South Africa and from the National Association of Automotive Manufacturers of South Africa (NAAMSA) publications and related communications.

One of the biggest challenges in the formalizing of a policy is access to relevant qualitative data that captures the thinking behind a policy. Developing the MIDP incentive model required specific understanding of the intentions of the model promoters and the assumptions underlying the dispensation. Such data was not explicit in the numerical and written data sources. It is widely acknowledged by a number of leading authors on system dynamics modeling that the most important data required for building a system dynamics model is often qualitative [23]. Specific to policy work, subsequent formulation of a dynamic hypothesis and formulation of a qualitative model requires insight into the mental models of role players [25], [35]. Key variables underlying behavior of interest resides in the mental database of some of the actors [31]. Sterman [35] asserts that more often mental data cannot be accessed directly but must be elicited through interviews, observation and other methods. In order to access qualitative data, the researcher usually needs to interact with people involved in the study situation over and above the use of archival research, data collection, interviews and direct observation or participation. The research had to include means to tap into information in stakeholders' recollection of the considerations that had led to particular policy decisions. In this regard, qualitative data to support the model building process was collected using two techniques: participant observation and discourse analysis. The researcher attended MIDP policy review meetings for a period 18 months. This was followed by discourse analysis of the qualitative information gathered from observation. In the following section, the development of the model is explained via a stepwise increase in scope.

IV. THE PAA-IEC MODEL STRUCTURE

The model was constructed sequentially for the two main incentives for automotive manufacturing in South Africa, the Productive Asset Allowance (PAA) and the Import Export Complementation (IEC) scheme. The PAA incentive allows receipt of import duty rebates based on investment, while the IEC allows receipt of duty offsets based on the value of exported local content [14].

V. THE PAA

Under the PAA, only investment in new and unused productive assets qualifies for benefit [17]. The value of assets qualifying for the PAA is therefore a proportion of total industry investment that can be captured by the equation:

$$\mathrm{P_{AA}I_t} = \alpha \mathrm{I} \quad (1)$$

where $P_{AA}I_t$ is the PAA qualifying investment in year t, α is the PAA qualifying investment fraction and I is total annual industry investment.

Benefit from the qualifying investment takes the form of import duty rebates and is set at 20% of the qualifying investment. The value of rebates that can be generated from a particular value of qualifying investment can be presented as:

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

where $P_{AA}RG$ is the PAA rebates generated per annum and the 0.2 is the existing PAA benefit fraction.

Since the benefit from the PAA is spread over a five-year period, the value of annual rebate certificates that can be generated is according to the equation:

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

where *RCR* represents the value of rebate certificate release per year and the 5 represents the five-year period over which the PAA benefit is spread.

The value of imports that can be brought into the country using PAA rebates depends on the prevailing import duty rate and the value of rebates issued in a particular year according to the equation:

$$P_{AA}RI = RCR / IMPORTDUTY \tag{4}$$

where $P_{AA}RI_t$ is the value of imports that can be brought into the country, using the PAA rebates and *IMPORTDUTY* is the prevailing import duty rate in the year under consideration.

Next, the feedback effect of PAA rebates was incorporated. The first step was to make industry investment endogenous. This was done by introducing an investment rate variable. Industry investment per year was set to depend on annual investment rate i.e.

$$I_t = I_{t-1}\left(1 + I_{rate}\right) \tag{5}$$

where I_{rate} is the annual investment growth rate.

Equation 5 depicts, implicitly, a potential exponential increase in industry investment over time. This baseline growth rate assumption was used at this stage. It is possible, however, to introduce more complex growth rate predictions.

One of the most important aspects of system dynamics modeling and a source of insights into system performance is the identification of feedback effects [36]. These constitute closed loops, where the level of outcomes has an effect on the level of inputs. In the PAA incentive model, two investment-determining factors were identified and introduced - domestic market and exports. Investment depends on planned production and planned production is, to a large extent, a function of projected domestic market size and export levels. Exports augment the domestic market size while imports, whether rebated or otherwise, reduce the effective domestic market. It is widely acknowledged that local market size is a major factor in investment location decisions particularly in the automotive manufacturing industry. Jenkins & Thomas [16] mention that the size of the local market is believed to the most important motivation for establishing European subsidiary companies in Southern Africa. As is to be expected, European subsidiary companies are strongly represented in South Africa's automotive manufacturing industry.

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 could benefit from the PAA incentive is through importing and offsetting duties payable using earned rebate certificates, firms will tend to import until they have exhausted import rebates received.

To account for the effects of domestic market size, exports and PAA rebatable imports on investment, a normal-investment-growth fraction variable was introduced. At this stage of model construction, both domestic market and exports were taken to be static. To the extent that the above three variables affect investment, actual investment growth fraction will differ from the normal growth fraction. The difference will be the effect emanating from a production potential factor (the basis of domestic production plans), which was postulated to be proportional to: *(domestic market + exports –PAA rebatable imports)/ (domestic market + exports)*. The logic of the equation is that as long as there are no rebatable imports, investment will grow at a normal rate dictated by the size of the domestic market and export potential.

The effect of PAA rebatable imports on the production potential factor, which in turn affect the actual investment growth fraction, constitutes a closed loop of the PAA incentive model (Figure 1).

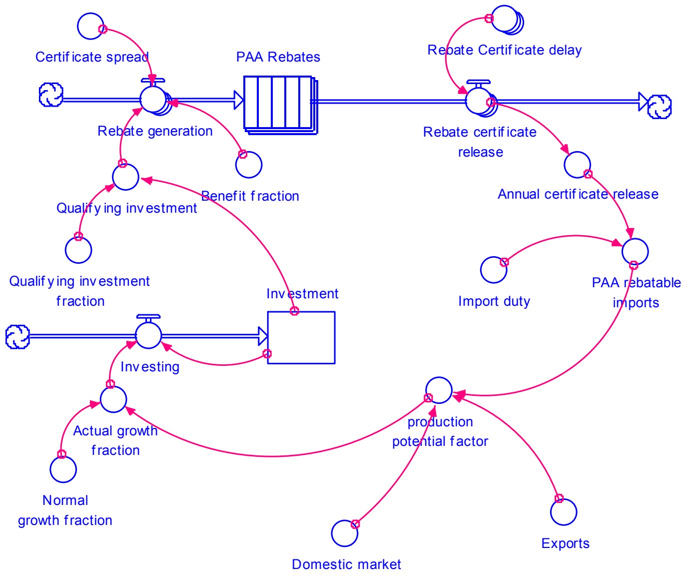

Figure 1: Closed loop stock-flow diagram for the PAA

By specifying initial model values and providing input values, the PAA model enables simulation of the value of rebatable imports under different scenarios pertaining to the PAA benefit policy rule.

As indicated previously, the import-export complementation scheme also contributes to rebatable imports. Therefore, the effect of rebatable imports on production plans was underestimated in the PAA model above, as it did not take into account additional rebatable imports generated through the IEC incentive scheme. In the following section, the model is extended to include the IEC, which also contributes to the value of rebatable imports for the industry.

VI. IMPORT-EXPORT COMPLEMENTATION MODEL STRUCTURE

Under the Import-Export Complementation, firms earn Import Rebate Credit Certificates (IRCCs), based on a proportion of exported local content. Exports were specified as being determined by an export growth rate, which rate was assumed to be determined exogenously – locally based vehicle assemblers' exports are largely dependent on parent company decisions. As such, the equation for industry exports per year could be presented as:

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

where E_t is total industry exports per annum in year t, and β is the export growth rate fraction.

The exported value of local content is captured by the equation:

$$ELC = ELCF * E_t \tag{7}$$

where *ELC* is the exported value of local content and *ELCF* is the exported local content fraction.

In calculating the IRCC value to be awarded to an exporting entity, the exported value of local content is discounted at a rate determined by Government. The IRCC value generated, therefore, is a function of exported local content and the exported local content beneficiation fraction as determined for a particular year. Equation (8) below captures this relationship:

$$IRCCVALUE = ELC * LCBF \tag{8}$$

where *IRCCVALUE* is the value of IRCCs generated per year, and *LCBF* the export local content beneficiation fraction.

By specification, the value of rebatable imports generated under the IEC in a particular year is equivalent to the value of IRCCs issued and is independent of the import duty rate.

Given this further adjustment, IRCCs generated under the IEC adds to the overall stock of industry rebatable imports. To estimate the overall effect of rebatable imports on production plans, the PAA model and the IEC model were combined. A new variable, namely industry rebatable imports, which was a summation of PAA rebatable imports and IRCC rebatable imports was introduced. The direct link between PAA rebatable imports and production plans was removed and instead a link between PAA rebatable imports and industry rebatable imports on one hand, and IRCC rebatable imports and industry rebatable imports on the other, was created. Thereafter, industry rebatable imports were linked to the production potential factor. An important aspect to take note of, under the combined PAA-IEC model, is the fact that exports and the domestic market were allowed to vary over time through the introduction of respective projected growth rates.

For completeness of structure, the PAA-IEC model was extended to include a "industry trade balance" variable. Introducing the trade balance variable allowed sensitivity analysis of the industry trade balance account in response to a policy decision on the PAA and IEC incentives of the MIDP. Trade balance trend was assumed to be a significant indicator of industry competitiveness in the international market.

The variable "Industry imports" was specified as an endogenous variable that depended on the import decision. The domestic market and the value of rebatable imports at industry level influenced the import decision. Before a firm within the industry could import, it had to have some insight into how much imports the domestic market could absorb. After establishing the import absorption capacity of the domestic market, the firm would have to consider the almost mandatory import it has to undertake in order to make use of import rebates earned. Hence, it was postulated that the domestic market and rebatable imports were determining factors of the import decision. If there was no commensurate increase in the domestic market, there was a high likelihood that as rebatable imports increased, industry imports would also increase.

In quantifying the part of the model underlying the import decision, the impact of domestic market and rebatable imports on imports growth fraction was specified as being dependent on the ratio of industry rebatable imports and on the domestic market. This impact declined as the value of rebatable imports tended toward the domestic market size. Figure 2 presents the extended PAA-IEC-Trade Balance model structure. The PAA-IEC-Trade Balance model in Figure 2 could be quantified and used to simulate effects of the PAA and IEC policy variables on industry investment. It is noted that for full modeling of trade balance dynamics, the effect of another lesser production related element of the incentive package, the duty free allowance, would have to be added in a manner similar to the above process. As its contribution does not alter the logic of the model materially, it is not included to simplify the analysis.

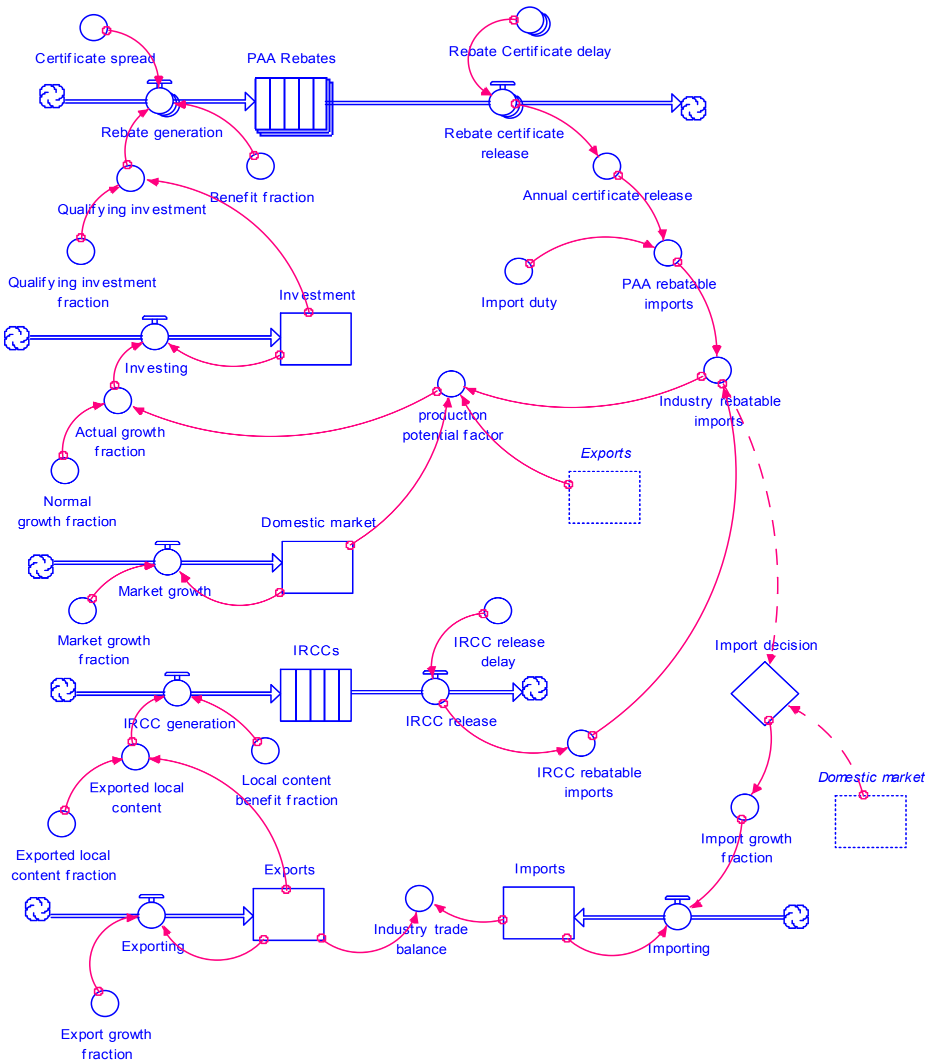

Figure 2: PAA-IEC-trade balance model structure

VII. MODEL VALIDATION AND TESTING

Model validation, as an important step in creating confidence in a model, was done before policy scenario simulations. It was acknowledged that despite the wide use of the word 'validation' in modeling literature, models cannot be validated – if validation is taken to mean establishing truthfulness of the model. This is so because all models are simplified representations of reality developed with a mindset biased towards what the model is intended to simulate and for whom it is intended. What can be validated, however, are the analytical statements and propositions derived from the axioms of closed logical systems [36]. In fact, the issue is not about the validity of the model but its usefulness. When system dynamics practitioners refer to model validation, they are usually referring to ways to make the model useful and acceptable to the intended clientele, a process that is more subjective than scientific. Referring to model validation Forrester [11] wrote:

> *Objective model-validation procedure rests eventually at some lower level of judgment or faith that either the procedure or its goals are acceptable without objective proof.*

Model validation took the form of establishing that the developed model could, to a reasonable extent, replicate reference mode behavior of interest; in this case it was industry vehicle manufacturers' (also referred to Original Equipment Manufacturers – OEMs) investment. Although widely acknowledged that the objective of system dynamics modeling is not point prediction of a system's performance but rather to probe dynamics underlying a particular behavior, 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 problematic situation and as such cannot be useful. Richardson and Pugh [32] state that if a model cannot reproduce its reference behavior mode, it is invalid. The simulation base run showed that the model could endogenously replicate the smoothed reference mode behavior (Figure 3). Replication of the reference behavior from an endogenous perspective indicated that the model could be useful in indicating leverage variables or points of action that could influence the industry investment trend.

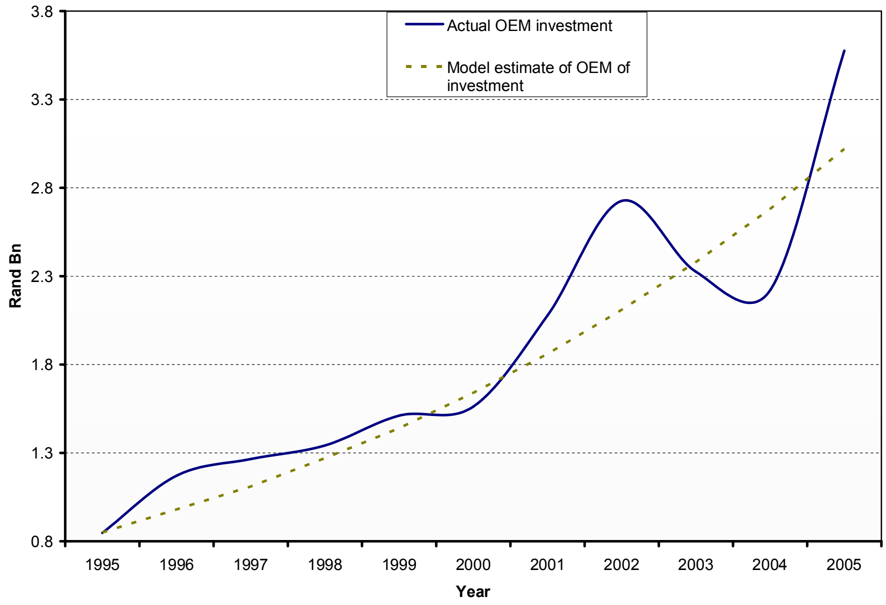

Figure 3: Model replication of the reference mode behavior

The complete set of Stella model equations for the base run reproducing the reference mode trend are presented in Appendix 1.

VIII. POLICY RULE CHANGES AND IMPLICATIONS TO INDUSTRY COMPETITIVENESS

Under the PAA, there are only two policy variables under control of Government – the PAA benefit fraction and the import duty. As such, policy decisions on the PAA relate fundamentally to adjusting the PAA benefit fraction and/or industry import duties. Model simulation of vehicle manufacturers' investment reveals that a change in the PAA benefit fraction has minimal influence on the investment trend. Figure 4 shows investment trend with the PAA benefit set at 0.2, 0.5 and 1.0 respectively. The insensitivity of investment to PAA benefit fractions points to the fact that investment in the country is more likely a function of domestic economic fundamentals, rather than of incentives as a particular policy lever.

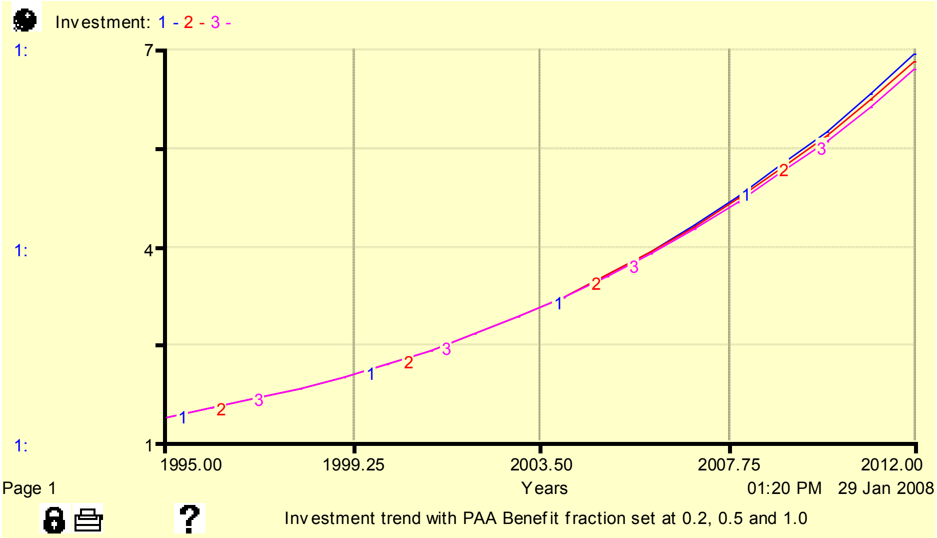

Figure 4: OEM investment trend (billion rand*) PAA benefit fraction set at 0.2, 0.5 and 1.0 [Trend 1, 2 and 3 respectively]

On the other hand, a change in import duties did have a noticeable effect on OEM investment in the medium term. Model simulation showed that in 2012, investment level by OEMs would be a billion rand (some USD 130 million) less if import duties were to be reduced from the 30% to 5% (Figure 5). The inverse relationship between import duty rate and domestic investment suggests that size of the domestic market is an important determinant of domestic investment. Lowering of import duties encourages automotive imports which in turn replaces local supply to the domestic market, reducing local production potential, consequently leading to less planned investment. The reduction in domestic investment because of lowering import duty also indicates, implicitly, that the domestic industry is not competitive relative to other locations producing comparable automotive products including vehicles. Otherwise, imports would not increase, with a reduction in import duties, to the extent of causing an adjustment in domestic investment if the South African location was as competitive.

* Approximate exchange rate: 8 rand/USD

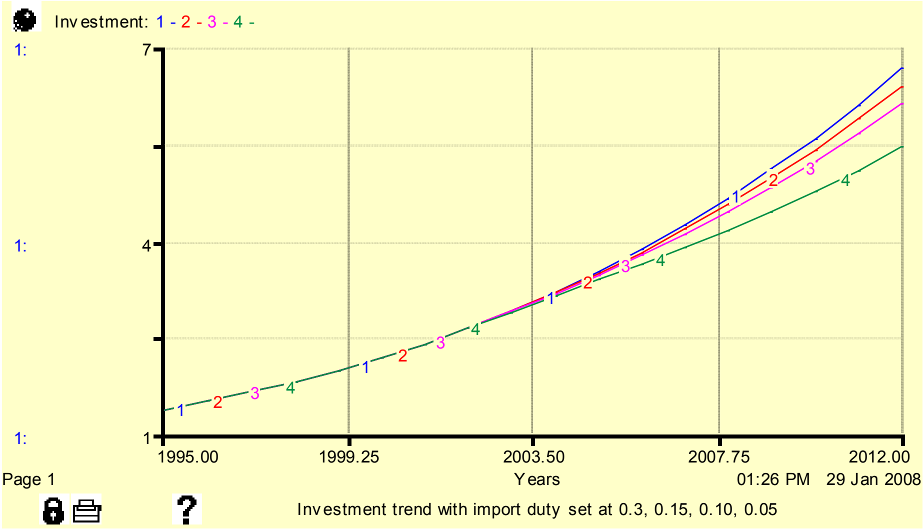

Figure 5: OEM Investment trend (billion rand) import duty set at 0.3, 0.15, 0.1 and 0.05 [Trend 1, 2, 3 and 4 respectively]

Under the IEC, policy makers have one policy lever under their control – the Exported Local Content Benefit Fraction (ELCBF). Model simulations showed that a change in ELCBF had a significant effect on investment. For example, OEM investment would reach some 9 billion rand in 2012 if ELCBF was to be reduced to 0.1, compared to less than 7 billion rand if the fraction remained at 0.9 (Figure 6).

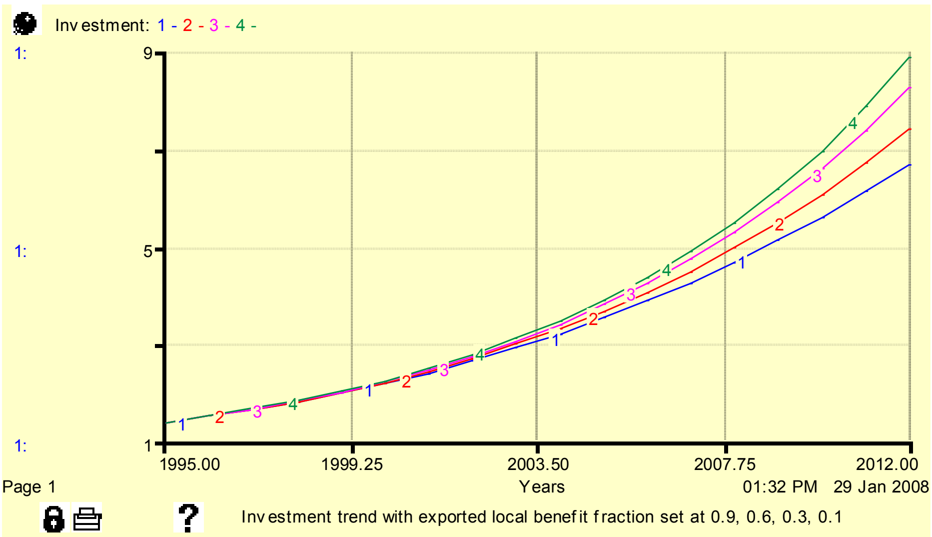

Figure 6: OEM Investment trend (billion rand) exported local content benefit fraction set at 0.9, 0.6, 0.3 and 0.1 [Trend 1, 2, 3 and 4 respectively]

Significant effect on investment occurred with a concurrent increase in PAA benefit fraction and reduction in ELCBF (Figure 7). According to model simulations, by reducing ELCBF from 0.9 to 0.1 and increasing the PAA benefit fraction from 0.2 to 0.9, the difference in projected investment would increase by more than 3 billion rand in 2012. Again, the biggest impact on investment emanates from the ELCBF. The simulation is based on a 'ceteris paribus' assumption but fundamentally it is indicative of the fact that the PAA benefit fraction and ELCBF are effective policy levers, in combination, in influencing industry investment.

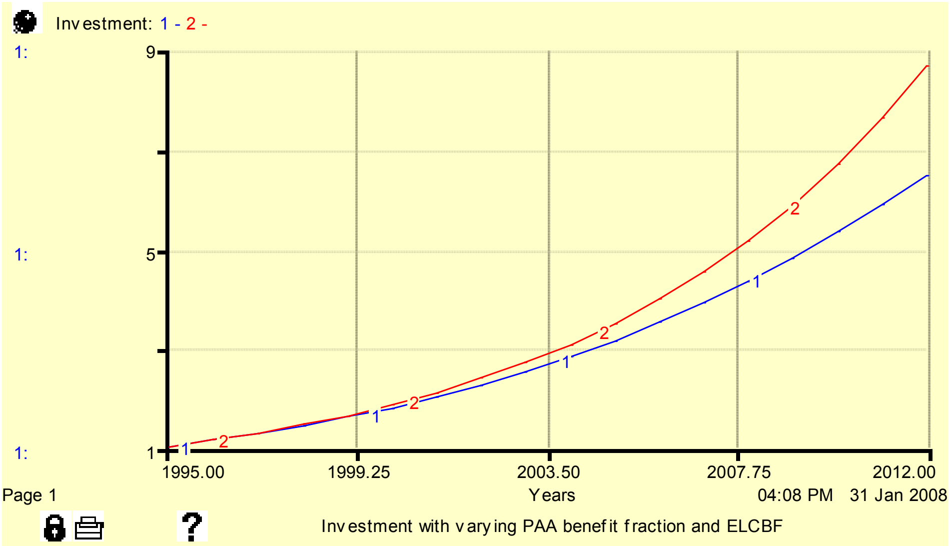

Figure 7: OEM Investment trend (billion rand) ELCBF set at 0.9 and PAA benefit faction at 0.2 and with ELCBF set at 0.1 and PAA benefit fraction at 0.9 [Trend 1 and 2 respectively]

What is important to note is that none of the policy decisions on the MIDP incentive model, as captured in Figure 4 to Figure 7, has a direct effect on the nature of investment. As such, the likelihood that the composition of automotive manufacturing industry investment in South Africa, as witnessed in the first 10 years of MIDP incentives, would change in the foreseeable future is minimal.

IX. INSIGHTS AND CONCLUSION

South Africa, being located at the southern end of the African continent, has a location disadvantage in terms of transport costs to and from major international vehicle markets. Given the oligopolistic nature of the global automotive manufacturing industry coupled with global oversupply of vehicles, countries need to provide vehicle manufacturers with extra motivation to invest in manufacturing in their respective economies. Through the offer of a package of incentives under the

MIDP, investment growth in the domestic automotive manufacturing industry was attained. Moreover, model simulations show that government could influence industry investment through adjusting incentive policy rules. However, the automotive incentive model has no explicit policy levers to influence the nature of industry investment that is, investment in R&D and resulting innovative activities vis-à-vis investment in machinery, tooling and equipment. To the extent that South Africa positioned the MIDP as competitiveness supporting intervention, the incentive model ought to have had a traceable effect on R&D and innovation activities in the local automotive industry. This has not been the case. The MIDP incentive model did not include investment in R&D or innovative activities as one of its endogenous variables that could be influenced by policy makers. Investment in productive assets and in R&D was assumed homogenous. The implicit expectation was that the industry would invest proportionally in R&D and innovation according to levels in countries of which industry competitiveness was to be emulated. One way through which R&D investment and innovative activities could have been made endogenous in the MIDP model, would be to make expenditure associated with such activities a qualifying criterion for the incentives. Overall, the modeling of the incentive policy reveals that the weakness of the MIDP to support industry competitiveness emanated from the model conceptualization. The model lacked policy leverage points to influence the nature of investment. A result, the model has proved to be a weak policy framework for supporting long-term industry competitiveness.

For industrial policy formulators and technology managers, South Africa's automotive manufacturing incentive model demonstrates one of the limitations of selective industry policy to support competitiveness among late developing countries. Well-intentioned policy interventions aimed at supporting industry competitiveness end up not yielding envisaged outcomes as a result of failure to have inbuilt policy levers that can influence a targeted industry to behave in a way that puts it on a competitiveness path. Many developing countries appreciate the need to become competitive and put in place various forms of incentives to motivate industry efforts towards competitiveness. However, many of the supportive policy frameworks lack practical policy levers to channel investment in R&D and innovative activities. Moreover, systemic factors, interdependencies and feedback effects within the industry that have a bearing on industry behaviour are often not taken into account.

This makes performance outcomes less predictable. Ensuring that an incentive policy does indeed support industry competitiveness requires formal policy modeling and identifying levers within the model that can influence industry to make competitiveness-oriented decisions. System dynamic modelling provides a useful way to do this.

Specific to investment incentives, it is imperative to note that firm investment is not homogenous in as far as industry competitiveness is concerned. The nature of enabled investment by way of offer of incentives or subsidies has a bearing on a particular industry's progress towards global competitiveness. In particular, innovation related expenditure is more correlated with attainment of competitiveness [39]. The effectiveness of incentives in supporting an industry's progress towards competitiveness, therefore, cannot be adjudicated without considering the nature of investment it enables. Parties involved in initiating and implementing incentives for competitiveness should consider explicitly how the proposed incentives would motivate investment that supports the competitiveness objective. The paper shows how formal modelling of incentive policy, using a system dynamics approach, can reveal whether a suggested incentive model has inbuilt policy levers to influence the nature of investment and hence can support industry competitiveness.

The modelling process had limitations that ought to be acknowledged even though not considered significant to change the paper's contributions. First, the model was not accurate in point prediction of investment overtime. However, since the model could replicate the general investment trend, it was considered acceptable. This was typical of system dynamics modelling that tend to emphasise replication of overall trend of a research aspect of interest rather than point prediction. The paper did not discuss calibration process and resulting parameters. Although such a discussion could increase confidence in the model, it was considered outside the scope of the paper. Moreover, the discussion had a potential to distract attention of a reader from the key objective of the paper. Similarly, the paper did not have a separate section focussing on model testing to reveal potential structural flaws. While structural testing was plausible from a theoretical perspective, it was not considered critical since the model was developed based on 'actual' structuring of the incentives, and taking into account administrative rules. Based the factual information, structural flaws in the model were less likely. Last, it would have been appropriate for the reference mode behaviour to relate to R&D investment and not industry investment in general. Doing so was constrained, however, by the fact that the incentive model was configured in such a way that investment was regarded as homogenous. The model was developed to capture, as closely as possible, the actual working of the incentive scheme. As a result, it could not simulate data pertaining to R&D in isolation. The paper tried to circumvent this limitation by first establishing that the model had no internal means to influence nature of enabled investment. Based on this, it could be deduced that investment in R&D was likely to remain less than 10% of total industry investment irrespective of level of investment.

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Appendix 1: Stella equations for the PAA-IEC model base-run

1. Domestic_market(t) = Domestic_market(t - dt) + (Market_growth) * dtINIT

   Domestic_market = 33.6

INFLOWS:

2. Market_growth = Domestic_market*Market_growth_fraction
3. Exports(t) = Exports(t - dt) + (Exporting) * dtINIT Exports = 4.2

INFLOWS:

4. Exporting = Exports*Export_growth_fraction
5. Imports(t) = Imports(t - dt) + (Importing) * dtINIT Imports = 16.4

INFLOWS:

6. Importing = Imports*Import_growth_fraction
7. Investment(t) = Investment(t - dt) + (Investing) * dtINIT Investment = 0.85

INFLOWS:

8. Investing = Investment*Actual_growth_fraction
9. IRCCs(t) = IRCCs(t - dt) + (IRCC_generation - IRCC_release) * dtINIT

   IRCCs = 0
10. TRANSIT TIME = varies
11. INFLOW LIMIT = INF
12. CAPACITY = INF

INFLOWS:

13. IRCC_generation = Local_content__benefit_fraction*Exported_local_content

OUTFLOWS:

14. IRCC_release = CONVEYOR OUTFLOW
15. TRANSIT TIME = IRCC_release__delay

16. 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

INFLOWS:

17. Rebate_generation[Annual_Certificate] = Qualifying_investment*Benefit_fraction/Certificate_spread

OUTFLOWS:

18. Rebate_certificate_release[1] = CONVEYOR OUTFLOW
19. TRANSIT TIME = Rebate_Certificate_delay[1]
20. Rebate_certificate_release[2] = CONVEYOR OUTFLOW
21. TRANSIT TIME = Rebate_Certificate_delay[2]
22. Rebate_certificate_release[3] = CONVEYOR OUTFLOW
23. TRANSIT TIME = Rebate_Certificate_delay[3]
24. Rebate_certificate_release[4] = CONVEYOR OUTFLOW
25. TRANSIT TIME = Rebate_Certificate_delay[4]
26. Rebate_certificate_release[5] = CONVEYOR OUTFLOW
27. TRANSIT TIME = Rebate_Certificate_delay[5]
28. Actual_growth_fraction = Normal__growth_fraction*production_potential_factor
29. Annual_certificate_release = ARRAYSUM(Rebate_certificate_release[*])
30. Benefit_fraction = 0+STEP(0.2, 2001)
31. Certificate_spread = 5
32. Exported_local_content = Exports*Exported_local__content_fraction
33. Exported_local__content_fraction = 0.7

34. Export_growth_fraction = CGROWTH(27)
35. Import_duty = 0.3
36. Import_growth_fraction = (CGROWTH(12)*Impact_of_rebatable_imports_and__domestic_market_on_imports)
37. Industry_rebatable__imports = IRCC_rebatable__imports+PAA_rebatable__imports
38. Industry_trade__balance = Exports-Imports
39. IRCC_rebatable__imports = IRCC_release*1
40. IRCC_release__delay = 1
41. Local_content__benefit_fraction = 0.9
42. Market_growth_fraction = CGROWTH(9)
43. Normal__growth_fraction = 0.15
44. PAA_rebatable__imports = Annual_certificate_release/Import_duty
45. production_potential_factor = (Domestic_market+Exports-Industry_rebatable__imports)/(Domestic_market+Exports)
46. Qualifying_investment = Investment*Qualifying_investment_fraction
47. Qualifying_investment_fraction = 0.8
48. Rebate_Certificate_delay[1] = 1
49. Rebate_Certificate_delay[2] = 2
50. Rebate_Certificate_delay[3] = 3
51. Rebate_Certificate_delay[4] = 4
52. Rebate_Certificate_delay[5] = 5

Import decision

53. 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, 1.29)