An analysis of possible effects of developmental pricing: A simulation study of the polypropylene industry in South Africa

by

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Declaration

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Date: March 2017

Abstract

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Beneficiation of locally extracted minerals to produce fully processed, high-value utility products is currently limited in South Africa. However, in the polypropylene value chain, locally mined coal is fully beneficiated to produce petroleum equivalent fuels and chemicals. The polypropylene value chain contributes fully processed, high utility products for use in various sectors of the economy, including the plastics industry. The Departments of Mineral Resources (DMR), Trade and Industry (DTI), have respectively identified the petroleum and plastics industries as some of the priority industries for intervention in the beneficiation strategy. The polypropylene upstream industry is currently dominated by China, with capacity representing 19% of global supply, while South Africa only accounts for 1%. However, the current capacity in South Africa represents 53% of polypropylene supply on the African continent. The current study investigated possible effects of a *cost-plus* developmental pricing policy as a beneficiation strategy in the polypropylene upstream industry. The study focussed on evaluating possible effects of *cost-plus* pricing on the future attractiveness for investment in capital projects to expand polypropylene production capacity in South Africa. The study demonstrated a systematic approach combining simulation and decision models to account for unavailability of full information and high uncertainties in estimates for quantitative appraisals during industrial policy analysis. The study combined value chain analysis using the global value chain (GVC) framework and Monte Carlo (MC) stochastic simulation methodologies to evaluate the possible impact of developmental pricing. The GVC framework was used to analyse the polypropylene upstream value chain with respect to governance and input/output structure. The MC simulation was applied to a discounted cash-flow (DCF) model on net present value (NPV). The approach presented in this research accounts for limited or asymmetric information, high competition and uncertainty in the local polypropylene industry. In addition, this systematic approach to industrial policy analysis appears to be useful in achieving beneficiation strategy objectives in highly competitive, highly regulated globalised industries. This can enable policy-makers to identify measurable impacts in formulating policies for beneficiation strategies. In South Africa, beneficiation strategies for the polypropylene and plastics industry can focus on identifying other raw materials to compete with existing value chains in order to stimulate more upstream competition. This can allow local production of more internationally competitive upstream products and offer better prices to the downstream industries.

Opsomming

Waardeketting analisie van effekte van ontwikketting pryse op die mededingendheid van die polimeer bedryf in Suid-Afrika

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Waardetoevoeging van inheemse minerale met die doel om volledig geprosesseerde, hoë-waarde nutprodukte te produseer is tans beperk in Suid-Afrika. Nietemin, in die polipropileen waardeketting word die waardetoevoeging van plaaslike steenkool ten volle gedoen deur die produksie van petroleum-ekwivalente brandstowwe en chemikalieë. Die polipropileen waardeketting dra geprosesseerde produkte van hoë nut by, vir gebruik in verskeie sektore van die ekonomie, insluitende die plastiekindustrie. Die Departement van Minerale Hulpbronne (DMR) en die Departement van Handel en Nywerheid (DTI) het die petroleum- en plastiekindustrie onderskeidelik geïdentifiseer in die waardetoevoegingstrategie as van die prioriteit-industrieë vir ingryping. Die stroomop industrieë van die hoë-waarde polipropileen waardeketting word tans deur China gedomineer, met China wat 19% van die wêreld se produksie kapasiteit verteenwoordig, terwyl Suid-Afrika slegs 1% verteenwoordig. Nietemin, Suid-Afrika verteenwoordig 53% van polipropileen produksie kapasiteit in Afrika. Dié studie ondersoek die moontlike gevolge van die koste-plus ontwikkelingsprysbeleid as ‘n waardetoevoeging strategie in die stroomop polipropileen industrie. Die studie het gefokus op die ondersoek van moontlike koste-plus prysregulering op die toekomstige aantreklikheid van beleggings in kapitaalprojekte om die polipropileen produksiekapasiteit in Suid-Afrika te verbreed. Die studie demonstreer ‘n sistematiese benadering, wat simulasie en keuse-modelle kombineer om voorsiening te maak vir die onbeskikbaarheid van volledige informasie en hoë onsekerheid in skattings vir kwantitatiewe evaluerings gedurende nywerheidsbeleid-analise. Die studie het waardeketting-analise van die globale waardeketting (“GVC”) raamwerk en Monte Carlo (MC) stogastiese simulasie gekombineer om die moontlike impak op ontwikkelingskoste te evalueer. Die “GVC” raamwerk was gebruik om die polipropileen-industrie waardeketting, met betrekking tot die bestuur en inset/uitset struktuur te analiseer. Die MC simulasie studie is uitgevoer op ’n verdiskontering van kontantvloei (DCF) model vir netto huidige waarde (NHW) evaluering van kapitale uitgawes vir kapasiteit toevoegings in die laaste dekade. Die benadering in die navorsing maak voorsiening vir beperkte of asimmetriese informasie, hoë kompetisie en onsekerheid in die plaaslike polipropileen industrie. Die sistematiese benadering tot nywerheidsbeleid-analise blyk sinvol te wees om die waardetoevoegingstrategie se uitkomste te evalueer in ‘n hoogs kompeterende, hoogs gereguleerde geglobaliseerde industrie. Dit kan beleidsmakers in staat stel om meetbare impakte in die formulering van beleide vir waardetoevoegingstrategieë te identifiseer. In Suid-Afrika kan waardetoevoeginstrategieë vir polipropileen en plastiek-nywerhede fokus op die identifisering van grondstowwe om te kompeteer met bestaande waardekettings om stroomop kompetisie te stimuleer. Dit sal plaaslike produksie in staat stel om meer hoë-waarde produkte te produseer wat kompeterend is op ‘n internasionale vlak en beter pryse te bied in stroomaf industrieë.

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I would also like to thank some of the experts in risk modelling and the plastics industry experts who participated in the study to verify and validate my assumptions and understanding about the industry, including but not limited to: Francois Joubert from Kwanto Risk Management, Will van der Merwe from Palisade, Mr Anton Hanekom from PlasticsSA, Mr Bernhard Mahl from Safripol, Jarrett Geldenhuys from Investec, Tinashe Kapuya from Agbiz, Reena das Nair and Pamela Mondliwa from the University of Johannesburg. Without their passionate, participation and valuable input, the verification and validation of my study would not have been possible.

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Dedications

I would like to dedicate this thesis to Rosemary and Pswerukai Gova, may you continue to stay in God's favour

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List of abbreviations

Units

coe	crude oil equivalent
ktpa	kilotons per annum
Mtoe	million ton oil equivalent
Mtpa	million tons per annum
Mt	million tons
T_g	glass transition temperature
toe	ton oil equivalent

Abbreviations

AIC	Autarkic Industrial Policy
AMSA	Arcelor-Mittal South Africa
ASGISA	Accelerated & Shared Growth Initiative for South Africa
BC	Beijing Consensus
BDA	Barcelona Development Agenda
CAPEX	Capital expenditure
CIP	Competitive Industrial Policy

CTL	Coal-to-liquid
DCF	Discounted cash-flow
DMR	Department of Mineral Resources
DTI	Department of Trade and Industry
ECPR	Efficient component pricing rule
EOI	Export Oriented Industrialisation
FT	Fischer-Tropsch
GDP	Gross Domestic Product
GEAR	Growth, Employment and Redistribution
GTL	Gas-to-liquid
GVC	Global Value Chain
HCI	Heavy and Chemical Industry
IEA	International Energy Agency
IPAP	Industrial Policy Action Plan
IPP	Import parity pricing
IMF	International Monetary Fund
IRR	Internal Rate of Return
LDPE	low density polyethylene
LPG	Liquefied petroleum gas
MDG	Millennium Development Goals
MEC	Mineral Energy Complex
MPRDA	Mineral and Petroleum Resource Development Act
NATREF	National Petroleum Refiners of SA (Pty) Ltd

NDP	National Development Plan
NGP	New Growth Path
NIC	Newly Industrialising Countries
NIPF	National Industrialisation Policy Framework
NPV	Net Present Value
OECD	Organization for Economic Cooperation and Development
OPEX	Operating expenditure
PDH	Propane dehydrogenation
PE	Poly(ethylene)
PMMA	Poly(methylmethacrylate)
PP	Poly(propylene)
PPU	Propylene purification unit
PTFE	Polytetrafluoroethylene
PVC	Poly(vinyl chloride)
ROR	Rate Of Return
WACC	Weighted Average Cost of Capital
WC	Washington Consensus
WTO	World Trade Organisation
SANEDI	South African National Energy Development Institute
SASOL	South African
UNIDO	United Nations Industrial Development Organization

Chapter 1

Introduction

Section 1.1 of this chapter will briefly outline the background of the study to highlight why the research was conducted. Section 1.2 and Section 1.3 will respectively discuss the research problem and main aim of the study. The scope and limitations of the investigation will be discussed in Section 1.4, while Section 1.5 will outline how the rest of the report is structured.

1.1 Background of the study

The polymer industry is one of the well-established industries with a high potential for contribution to economic growth, job creation and downstream industrial development, as identified by the Departments of Trade and Industry (DTI) and Mineral Resources (DMR). This is due to its multiple linkages and reliance on locally produced petroleum-related products as enunciated by the SANEDI (2011) and the DTI (2015). According to the DTI (2015), one of the major problems faced by the South African polymer industry is excessive upstream pricing of inputs, especially import parity pricing practices. The knock-on effects of these high input costs include among other factors; low demand for local products by export markets due to poor price competitiveness and subsequent import penetration by low-cost, value added plastic products, off-setting the balance of trade.

One of the major proposals to overcome this bottleneck is *developmental pricing*, in the form of a bill proposed by the DMR (2013), to amendment the Mineral and Petroleum Resource Development Act of 2002 (MPRDA). The bill was still under review at the time of writing, to address some concerns on other aspects of the bill not satisfactory to the President and other stakeholders, after being approved in parliament. According to the bill, *developmental pricing* is a stipulated pricing methodology which will be based on domestic beneficiation needs for minerals, petroleum or mineral products determined by the DMR. In its current form, the bill does not specify what pricing methodology will be enforced under the *developmental pricing* conditions. The DMR (2013), through the bill, believe that empowering the state to proportionately restrict export of mineral and petroleum products will enable easy stipulation of a discretionary pricing methodology to be adopted by producers when selling inputs to downstream industries for beneficiation purposes, an approach supported by Jourdan (2014). The ParlyReportSA (2013) notes that the ambiguity of beneficiation conditions contemplated in the bill at the time stirred a lot of uncertainty among stakeholders in the industry. Some of the concerns include; what price methodologies the DMR will institute, the possible impact this might have on investment returns and its effectiveness in meeting intended development goals as pointed by Stillman (2011); Allix (2015) and Seccombe (2015).

The current study attempts to bridge this gap by analysing the possible impacts of an applicable developmental pricing methodology on the polypropylene value chain as an illustrative proxy case for the larger plastics industry, as a possible approach to evaluate such quantity based industrial policies. This study proposes a techno-economic analysis approach on a relevant value chain in the polymer industry to evaluate the effectiveness and possible impacts of a developmental pricing industrial policy. The evidence gathered in this study will be used to highlight possible effects of cost-based price regulation to achieve developmental goals of securing supply of feed-stocks at reasonable prices for downstream industries to ensure competitive pricing of local plastic products.

During the course of this study, the *developmental pricing* methodology which had been in use in the steel industry since 2011 was "cost-plus 10%". The policy was renegotiated by stakeholders in the steel industry during the third quarter of 2016 and an alternative "import weighted basket" pricing methodology was proposed. To that affect, "cost-plus" pricing was chosen for analysis in this study since it was the most likely pricing methodology to be considered by the DTI for the polypropylene industry based on information available in the course of the study.

1.2 Research problem

In South Africa, locally extracted minerals are not fully beneficiated or processed to their final, usable products. However, in the polypropylene value chain, locally mined minerals such as coal, are fully beneficiated to produce petroleum equivalent fuels and chemicals, to the extent of contributing fully processed, high utility products for use in various sectors of the economy. The DTI and DMR are making attempts to propose industrial policies to ensure a trickle-down effect of upstream "comparative advantages" to improve global competitiveness of downstream industry exports.

Traditionally, industrialisation strategies and development initiatives have been informed by the identification of key local value chains for promotion through both quantitative and qualitative policy analysis. However, there is limited literature on techno-economic policy analysis for heavy and chemical industry (HCI) strategies focusing on resource rich, newly industrialising countries (NICs). Some literature was available on price regulation limited to service industries such as telecommunications, but not on promoting export-oriented industrial development.

This study will explore policy analysis approaches to appraise cost-based price regulation in industries with high uncertainties and high information asymmetry between agents, policy-makers and consumers, as is the case in South Africa. Net present value (NPV) and internal rate of return (IRR) are common tools used by organisations to identify and select capital projects for investment. These tools were applied in the study to assess how developmental pricing can influence capital investment decisions.

1.3 Research aim and objectives

The main aim of this study is to investigate possible effects of developmental pricing on attractiveness of future investments in the polypropylene upstream industry in South Africa.

The main goal was to perform a quantitative, techno-economic simulation study to evaluate developmental pricing effects on expected future returns from capital investments in the polypropylene upstream industry.

In order to accomplish these goals, the main objectives for the current study seek. to;

- Review literature on industrial policy strategies for newly industrialising countries and methods for appraising industrial policy;
- Map and analyse the polypropylene upstream value chain in order to assess the relationship between global prices and capital project investment decisions in South Africa;
- Develop an appropriate model to evaluate attractiveness of the polypropylene upstream industry for future capital investments;
- Perform a simulation study to evaluate attractiveness of the polypropylene upstream industry for developmental pricing compared to the current state.

1.4 Research scope and limitations

The polypropylene industry is used as a representative value chain for the plastics industry for beneficiation of the coal and oil chemical feedstocks. The current study mainly focuses on evaluating the possible effects of the currently proposed developmental pricing, using a similar approach to the one instituted in the steel industry. The study specifically investigates what the possible impact may be on the investment decisions for the upstream PP industry. The investigation is limited to possible effects of the policy related to capital project evaluation for upstream players in the polypropylene industry.

The simulation case study depicts possible capital expenditure decision criteria on future projects related to upgrading and expanding operations for the upstream industry. Analysis of possible effects of developmental pricing will concentrate on economic viability and attractiveness during a ten year tenure of the policy for this study. As a result of limited information on all economic factors of production in the polypropylene industry, the current study evaluates economic viability based on uncertainties in production volumes and prices for individual products along the value chain.

1.5 Thesis outline

In order to achieve goals and objectives of this study, the study proceeded as outlined in Fig1.1.

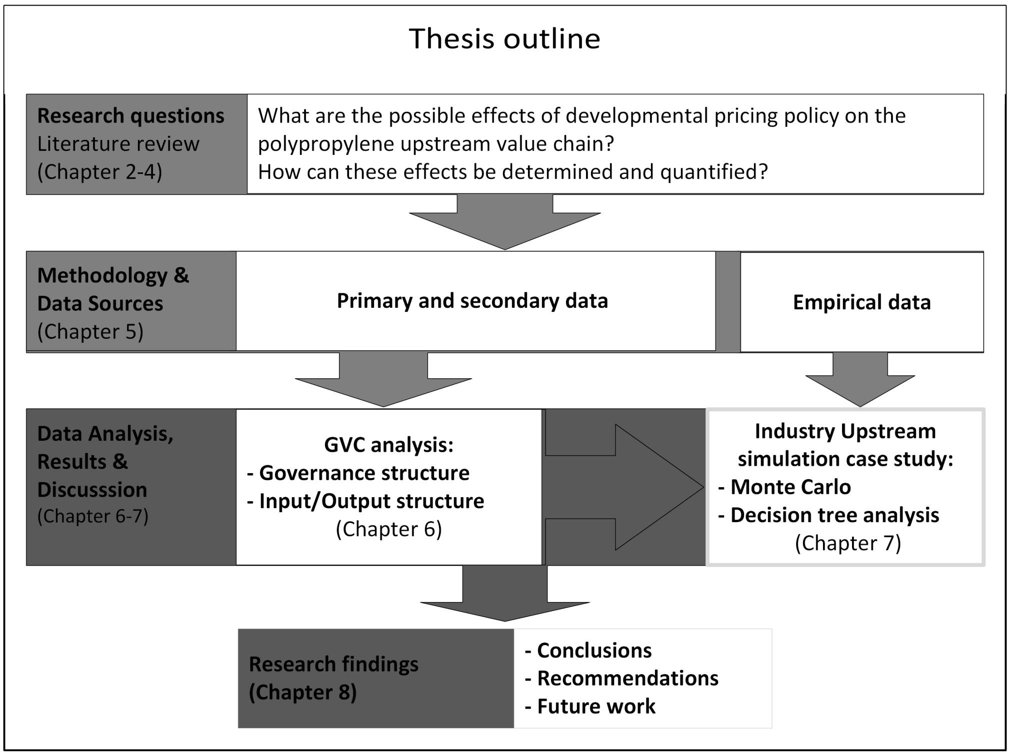

Figure 1.1: Summary of thesis outline

Chapter 2 and Chapter 3 will review literature to understand pertinent issues and various aspects of socio-economic and industrial development by newly industrialising countries (NICs), especially developmental states, such as South Africa. Chapter 4 explores some of the merits and de-merits of industrial policy based on price regulation as a socio-economic and industrial development tool, the implications on stakeholders, some regulatory considerations and possible tools for analysis of such a policy. Chapter 5 will then discuss the techniques chosen for the study, including some assumptions, challenges and limitations of the study based on the chosen techniques. Results for value chain analysis will be discussed in Chapter 6, while results for the simulation study will be discussed in Chapter 7. Based on evidence from these findings, some conclusions and recommendations will be drawn in Chapter 8.

Chapter 2

Literature review: Development strategies for Newly Industrialising Countries (NICs)

This section explores the various approaches employed by policy-makers to develop industries in general, and heavy and chemical industries (HCIs) such as the plastics industry in particular. The discussion will more specifically focus on newly industrialising countries (NICs) and the various considerations and policy implications economic development strategies adopted may have on capital intensive industries, individual companies and where applicable, international trade in global economies.

Firstly, Section 2.2 will explore mid to late 20^{th} century East Asian economic development models and how they might have inspired some of the major economic development prescriptions previously recommended for other NICs in the last three decades by global development agencies. This will be followed by an interrogation of the Washington Consensus (WC) as the bedrock of industrialisation strategies recommended for NICs by development agencies in Section 2.3. Section 2.4 will highlight how these recommendations have reshaped both local and global value chains (GVCs), as well as socio-economic development for NICs such as South Africa. The discussion will proceed to cover key aspects on how other NICs have successfully used industrial policy as a tool for HCI development strategies in Section 2.5, including key arguments posed by advocates and proponents, for and against industrial policy respectively. Section 2.6 will explore economic development strategies independently devised by South Africa to pursue a developmental state agenda and how the developmental pricing industrial policy under investigation ties in with that objective.

2.1 Introduction

Priewe (2015) identifies eight key economic strategies which are aimed at setting priority goals and explains how they can be achieved by defining policy tools to be used together with trade-offs and time frames. The first four strategies which are considered mainstream include the WC, neo-liberalism, good governance and Millennium Development Goals (MDGs). The remaining four were considered more specific and contestable, such as inward or outward development with export-led growth, industrialisation or growth with predominant primary goods exports and lastly, foreign-aid-based development (Priewe, 2015). This discussion will mainly focus on the WC strategies in order to show how it influenced the political economy of developmental states such as South Africa, at the turn of the 21^{st} century. But first, a brief overview of some of the other strategies applied during economic growth in selected East Asian countries will be undertaken, since literature suggests that these strategies have influenced formulation of the WC for implementation by other developing countries.

2.2 The *East Asian Miracle economic development model*

Studies conducted by Auty (1994a,b) on Brazil, China, Korea, India, Mexico and Taiwan identified two major NIC policy strategies that were common in early stages of HCIs. These two Industrial policy approaches were namely autarkic (AIP) and competitive industrial policies (CIP). Gereffi (2014) prefers calling AIP and CIP approaches import-substitution (ISI) and export-oriented industrialisation (EOI) models respectively.

The AIP policy regimes were found to be prominent in the early stages of HCI development around the 1950s, and the strategy was centred around substituting imports and infant industry protection as elaborated by Auty (1994*a*,*b*); Owen (2012) and Stiglitz *et al.* (2013). Policy decisions at this stage were mainly concerned with three facets; creating a conducive macroeconomic environment for autarky or self-sufficiency, protecting infant industries and dictating priorities in HCI projects. In essence, Auty (1994*a*,*b*) views AIP policy approaches as avenues that were used by NICs to pave the way for other policy decisions. The ultimate goal was the establishment of macroeconomic policy frameworks to dictate the degree of infant industry protection and prioritisation of HCI development initiatives. The success of this policy approach at early stages of HIC development varied between the studied NICs to reach a definite conclusion.

Policy approaches centred around CIP were adopted at much later stages of industrialisation, mostly between 1970 and early 1990s to replace AIP promoting labour-intensive manufacturers. This CIP approach tended to focus on liberalising export-driven sectors and increased competitiveness to boost domestic wages, aided by market liberalisation. A general shift from exports derived from labour-intensive to capital-intensive HCIs was observed followed by a subsequent shift to skill-intensive engineering and knowledge-based products. For different NICs, various stages of implementing this policy approach were involved, points out Auty (1994*a*,*b*).

However, it is important to note that CIP had less impact than AIP since it was to a greater extent facilitated by AIP. In the early stages of industrialisation, promotion of labour-intensive industries dominated, making products destined for more lucrative export markets and simultaneously absorbing surplus labour. At this stage, a turning point was reached where the domestic labour market was exhausted and triggered wage increases to accommodate productivity. This inherently enabled gradual abandonment of lowly productive sectors in later stages in favour of those with competitive advantages which further boosted exports and increased domestic wages together and, hence, local purchasing power to improve economic performance further (Owen, 2012; Stiglitz *et al.*, 2013). Gereffi (2014) warns that policy approaches were not as clear-cut between AIP and CIP as suggested by Auty (1994*a*,*b*). Industrial policy is suggested by Gereffi (2014) to have been intertwined to include elements of both strategies, while shifting from easier to more difficult phases of both AIP and CIP.

2.3 The *Washington Consensus* economic development model

The second industrial policy approach that has been considered for NICs is the WC. However, there is still some debate among scholars around whether it should be viewed as a universal *neo-liberal* policy approach for adoption by NICs as argued by Gore (2000); Serra *et al.* (2008); Priewe (2015).

Gore (2000) describes the WC as a universal convergence towards market-oriented, stabilisation and structural adjustment policy approach proposed to developing countries in early 1980s by Washington-based institutions. These institutions mainly included the International Monetary Fund (IMF), World Bank and US Treasury. Serra *et al.* (2008); Gore (2000) and Kennedy (2010) agree that the economic development strategy prescribed by the WC had three major policy reforms in its ten points[1]. Firstly, to "pursue macroeconomic stability by controlling inflation and reducing fiscal deficit". The second recommendation was trade and capital account liberalisation in order to open economies to the rest of the world. Lastly, it advocated "liberalisation of domestic product and factor markets through privatisation" (Gore, 2000; Serra *et al.*, 2008; Kennedy, 2010).

Gereffi (2014) views the WC as an attempt by the US and UK to package the EOI model attributed to the later stages of the *East Asian miracle* and Latin America for developing countries. Serra *et al.* (2008) and Kennedy (2010) somewhat disagree with reasons for this view, but suggest that this was rather a response to curb state role in initiating industrialisation and import substitution witnessed in East Asia and Latin America.

According to Gore (2000) and Serra *et al.* (2008), the WC has been associated with 'market fundamentalism' or the view that markets solve economic problems unabated. This approach, as Gore (2000) and Serra *et al.* (2008) concur, is paradoxical, since "market failures are pervasive, especially in devel-

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[1] The ten points enshrined in the WC were: (1) fiscal discipline : eliminate public deficits; (2) public spending priority : withdrawals of subsidies and increased spending in health and education; (3) Tax reform : broaden tax base and lower tax rates; (4) interest rates : positive, determined by market; (5) exchange rates : market-oriented to reflect competitiveness; (6) trade liberalisation : open economy; (7) foreign direct investment : unrestricted; (8) privatisation of public enterprises; (9) deregulation of economic activity; (10) strict guarantee of property rights (Gore, 2000; Serra *et al.*, 2008; Kennedy, 2010)

oping economies predominated with imperfections in information, limitations in competition and incomplete markets", making these markets inefficient.

Serra *et al.* (2008) identifies critics of the WC for achieving limited economic growth in countries where it was implemented and suggests that it mostly benefited those at the top. Citing Latin America as a main example where growth was halved under the WC in comparison to import substitution economic policies, which Gereffi (2014) calls the ISI model, that preceded it (Serra *et al.*, 2008; Gereffi, 2014). Some scholars like Gereffi (2014) suggest that the WC was a success, proposing that the WC overcame the ISI model bias of smaller developing countries towards the limited domestic markets through affording them access to the benefits of scale economies. This is presumed to have allowed them to learn from exporting to larger trade partners. Gereffi (2014) believes that this has resulted in reinforcement of GVCs promulgated by the *East Asia miracle*. Gore (2000) to some extend concurs, arguing that criticisms against the WC have been fuelled by sustainable human development (SHD) advocates, with the impression that it focussed more on promoting GDP growth and less on a *people-centred* approach. This stance promulgates the notion that this presented a problem for policy analysis. This is because, as the SHD approach proposes, economic growth performance must not result in a mismatch with social performance.

However, WC sympathisers defend the approach by attempting to show that it reduces poverty, increases employment and delivers growth with equity by arguing that WC requires a different paradigm to evaluate industrial and economic policy (Gore, 2000; Cattaneo *et al.*, 2010; Barrientos *et al.*, 2011; Gereffi, 2014). Gereffi (2014) and Gore (2000) argue that economic growth was central to the success of East Asia and South America similar to the objectives of the WC. They further argue that depending on the effectiveness of economic analysis of how growth occurs for NICs, policy orientation blunders during implementation of the WC are very likely, hence the need for a new paradigm to appraise economic policy. This argument is strengthened by the fact that policy measures leading to the *East Asia miracle* were not a 'blueprint' like the WC, but were gradually changed and adapted to the initial conditions and external environment over time as the economy matured, as asserted by Gore (2000).

One problem that advocates of the WC level against its critics, identified by Serra *et al.* (2008) and Kennedy (2010), is that the current interpretation differs strongly from the original economic reform proposed by Williamson[1] and later adopted as the WC. Firstly, Serra *et al.* (2008) argues that it differs by narrowly focussing primarily on privatisation, liberalisation and price or macro stability. Secondly, it broadly focusses on more forms of liberalisation not initially proposed such as capital market liberalisation.

2.4 Post-Washington consensus and emerging theories

A few scholars have suggested that new, more sustainable economic development approaches have been formulated as alternatives to the WC for developing countries, but there does not yet seem to be consensus on which ones should be adopted. As outlined by Kennedy (2010); Ramo (2004) and Serra *et al.* (2008), examples include the Beijing Consensus[2], Monterrey Consensus[3], the Copenhagen Consensus[4], the Mexico Consensus[5], the Southern Consensus[6] and the Barcelona Development Agenda (BDA).

Serra *et al.* (2008) suggests that the BDA is of note, since it was an attempt by Williamson in September 2004, with the help of other economists, to correct misinterpretations in implementation of the WC. This team of economists

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[1] John Williamson was an economist at the Peterson Institute of International Economics in Washington DC who formulated the original WC in 1989 as indicated in these papers: i. Williamson, J. (1990). 'What Washington Means by Policy Reform', in J. Williamson (ed.), Latin American Adjustment: How Much Has Happened? Washington, DC: Institute for International Economics. ii. Williamson, J. (2002) 'Did the WC Fail?' Outline of speech at the Centre for Strategic and International Studies, Washington, DC.

[2] Proposed by Joshua Cooper Ramo (Foreign Policy Centre, 2004), advocated new measures of economic success opposed to GDP growth, such as innovation-based development, sustainability and level of equality. Self-determination was also promoted, unlike WC, i.e. globalisation on own terms, developing asymmetric capabilities to balance against the US.

[3] Promoted by United Nations and WTO secretary-general (Michael Moore): to reduce global poverty.

[4] Compiled from questionnaires to economists on ten steps to improve global welfare with US$50 billion, HIV/AIDS topped the list.

[5] Targeted improving gender equality in Latin America and the Caribbean.

[6] Proposed by Al Gore to support strategic integration into global economy. Advocated use of a wide-range of industrial policies to promote productivity growth, encourage government-business cooperation, decrease inequality, foster regional integration and cooperation.

did not refute the WC, instead, they warned that care needs to be taken by policymakers in how economic reforms that support WC are carried out. Furthermore, they discouraged international development organisations from attempting to copy institutions of rich countries for developing countries as these may be more harmful than beneficial.

For the purpose of this study, as demonstrated by Gore (2000) and Gereffi (2014), it will be argued that the WC indeed shifted domestic trade relations focused on import substitution in favor of global, more liberal, export-oriented ones. As a result of this, a new spatial and temporal frame of reference in paradigms from national to global development policy analysis will be considered. Globalisation necessitated development policy analysis that accounts for export-focussed, market-oriented approaches as the WC advocates. This therefore requires a shift from historicism (retrospective) to ahistorical (prospective) policy performance assessment as pointed out by Gore (2000). This approach has been strongly advocated by Gereffi (2014); Barrientos *et al.* (2011) and Cattaneo *et al.* (2013) with the introduction of GVC analysis, as will be discussed in Section 4.5.3.

Value chains post-Washington Consensus

Gereffi (2014) suggests that; post-WC, global economies have become more complex and dynamic economic networks with inter-firm and intra-firm relationships in many different geographic locations. This alteration of industrial organisation due to globalisation ushered in international competition and has restructured global production systems and trade Gereffi (2014). Supply chains in low wage areas were gradually organised around these GVCs to become labour-intensive export platforms for multinational firms (Gereffi, 2014). This has resulted in a shift in market power in industries, for example; in labour intensive industries, power has shifted to traders and retailers away from producers (Schmitz, 2005). This power shift was characterised by Schmitz (2005) as being dominated by global buyers, dictating terms for the rest of the value chain to operate under, deciding what will be produced, where, by which producers and at what price. Gereffi (2014) calls these emergent supply chains ’buyer-driven’ chains, developed in search of offshore consumer goods, to capture more value from accelerated offshore production in East Asia. These chains replaced 'producer-driven' commodity chains that had existed (Gereffi, 2014).

Humphrey and Schmitz (2002) assert that globalization has inserted global players into value chains in less developed countries and NICs. This has forced local industry development interventions in these NICs to leverage on labor-intensive industries and focus on "upgrading", to make better quality products and improve efficiency among other challenges. Failure to adapt value chains and industries to this paradigm forces them to shift their focus into more skilled activities to remain competitive, with respect to phases recognised by Cattaneo *et al.* (2013) as shown in Fig 2.1.

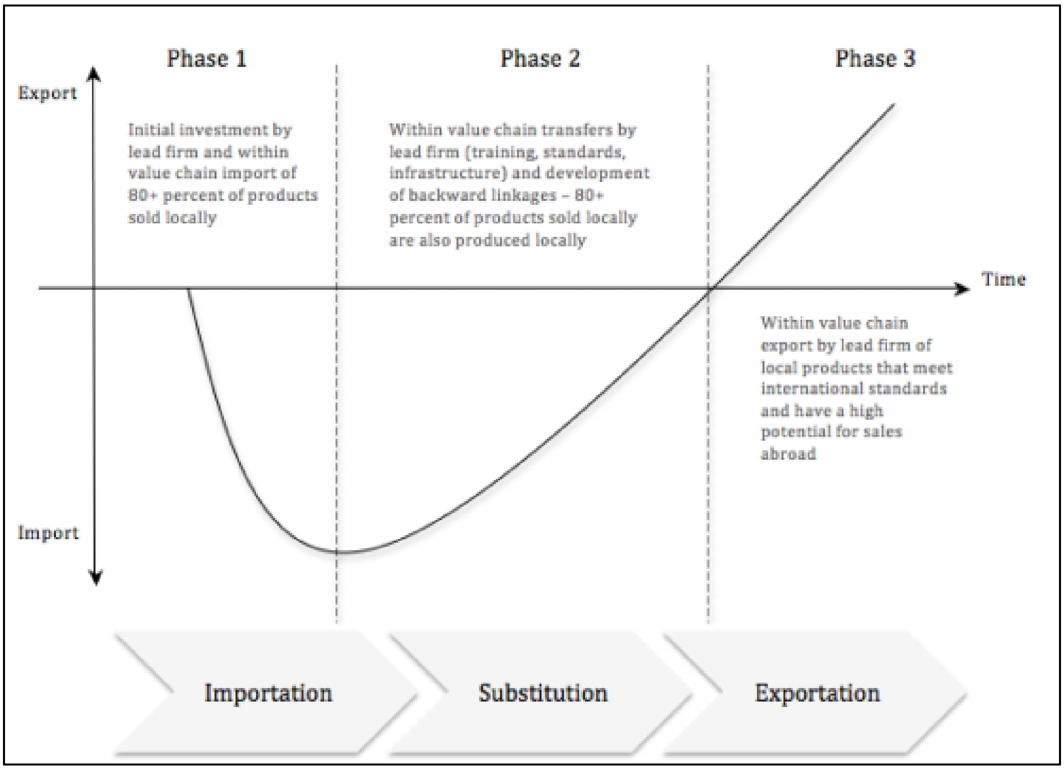


Figure 2.1: Phases followed by NICs towards globalisation. Source: (Cattaneo *et al.*, 2013, 5).

The globalisation value chain paradigm proposes a shift from importing, to import substitution, before finally having a productive sector exporting value-added products. As a result, the value chain paradigm requires an appropriate tool to analyze the impact of economic policy interventions which accounts for the multiple geo-political participants and their influence on economic development.

In agreement with Schmitz (2005), Gereffi (2014) is of the opinion that value chain analysis is suitable to identify leverage points to improve standards by putting pressure on local lead firms of GVCs to improve conditions (Schmitz, 2005; Gereffi, 2014). More specifically, the GVC framework is recommended by Gereffi (2014) for industrial policy analysis because it focusses on these globally expanding supply chains together with how value is created and captured in them (Gereffi, 2014). Humphrey and Schmitz (2002) also recommend use of the GVC framework to perform value chain analysis, since it reveals how global production and distribution systems are organized, especially how the structure of the industry is influenced by external forces as local producers acquire a lot of knowledge from interacting with global buyers (Humphrey and Schmitz, 2002).

In summary, the response to globalization advocated by the WC was for international companies to fragment and rationalize their supply chains to incorporate low-cost and more efficient producers from all over the world, resulting in the emergence of GVCs (Gereffi, 2014). This discussion will continue in Section 4.5.3, first, a quick discussion on the use of industrial policy as a tool for industrialisation of HCIs will be pursued.

2.5 Heavy and chemical industry (HCI) development strategies

Industrialisation strategies for HCIs are associated with various risks including high capital costs, long payback periods and technical complexity. According to Auty (1994*a*), HCI mainly includes basic metals, non-metals, minerals, chemicals, engineering and machinery. There is a lot of debate surrounding industrial policy as a strategy for industrialisation especially whether or not to adopt an industrial policy, and if so, what type of policy will be suitable to achieve developmental and macroeconomic goals specific for the country in question, argue Auty (1994*a*,*b*); Owen (2012) and Stiglitz *et al.* (2013). As a result of the close association of these sectors with multiple backward and forward linkages, the economic success of most NICs has hinged greatly on HCIs.

This makes HCIs highly instrumental in facilitating growth and development of new industries and forces NICs to embark on 'Big Push' industrialization programs, as suggested by Auty (1994*b*); Elgar (2012); Owen (2012).

As Baldwin (2013) and Priewe (2015) explain, 'Big Push' industrialization was focused on state-financed development of large industries despite lack of sufficient local demand to consume the products, in order to substitute imports. The rationale for this was mainly to offset trade deficits, while risking possible financial losses in the short-term from low consumption as demand for products grows slowly during the early industrial development phases. This brings us to the discussion on how best governments and policy-makers can then regulate activities in HCIs to achieve their macroeconomic development goals, given these considerations.

2.5.1 The Industrial policy controversy

Haines (2015) recognises industrial policy as a major component of economic planning, whose main objective is to influence resource allocation in order to accelerate attainment of development objectives. Elgar (2012) defines industrial policies as a variety of measures by governments to guide and control the structural transformation process of an economy with the aim to prevent market failures. Owen (2012) reinforces this definition by proclaiming that these measures are aimed at bringing about industrial outcomes different from those that would have occurred in free markets. These interventions range from defining rules of the competitive game, thereby affecting all firms in favour of participation of certain sectors or firms being prioritised by the development goals in the competitive game (Elgar, 2012; Owen, 2012).

The debate on whether or not to adopt industrial policies as a tool to boost industrial performance and drive economic growth has evolved from the time it was popularized after World War 2 to the recent Global Financial Crisis of 2008 (Auty, 1994*a*; Stiglitz *et al.*, 2013; Haines, 2015). Industrial policy approaches have evolved over the years especially after World War 2 when European countries had to formulate strategies to repair economic damages caused by the war, notes Haines (2015). Although scholars may be critical of a certain industrial policy in a specific context, there seems to be a general consensus that successful economies have been supported by policies promoting growth by accelerating structural transformation as opposed to rent-seeking approaches (also discussed by Elgar (2012); Olsthoorn and Wieczorek (2012); Kirkpatrick *et al.* (2012); Banda *et al.* (2015) and Tommaso and Rubini (2013)). Stiglitz *et al.* (2013) concur that the global challenge now is to 'identify specific policy levers and institutional framework that can generate optimal industrial policy results in different contexts' (Stiglitz *et al.*, 2013). However, industrial performance and development is also influenced by other policies and factors besides industrial policy. Competition policy, trade policy, educational policy, macroeconomic policy and training policy are some of the other policies suggested by Elgar (2012) and Stiglitz *et al.* (2013) as other important pillars necessary for industrial performance (Elgar, 2012; Owen, 2012).

Auty (1994*a*) sums up the two major divergent schools of thought that have emerged in the debate on industrial policy choices for countries embarking on HCI projects. The first school of thought takes the neo-liberal approach which argues for a free market economy with little government intervention or support to avoid the high risks associated with HCI investments. These scholars are informed by macroeconomic theory and econometric testing for their industrial policy critique. The second one is the institutionalist approach which advocates government intervention and support to create competitive advantage. Industrial policy discourse by institutionalists is governed by qualitative evaluation case studies at micro-economic level.

Neo-liberal argument

Neo-liberals are of the opinion that HCI investments are too high-risk to justify government support and intervention. Three major risks identified by Auty (1994) as major risk factors cited by neo-liberals for investing in HCI projects include high capital costs, long payback periods and technical complexity.

The risk associated with high capital costs is the opportunity cost of investing in few projects while foregoing investments in smaller, diverse industries which would otherwise spread risks and reduce the likelihood of failure. The fact that HCI investments generally have long maturation and payback periods also means that any external shocks like low demand may have negative implications on the industry. The complexity of technological and skills needs of HCI projects increases risk since this makes them overly dependent on successful coordination of complementary linked industries. Neo-liberals therefore believe the best path to HCI promotion is to liberalize the economy and let the market signal investment allocations. In this regard, private investors are expected to assume the risks associated with manufacturing industrial products and import products not produced locally (Auty, 1994*a*)

Institutionalist argument

Institutionalists, on the other hand are opposed to the neo-liberals' policy approach since they are of the opinion that it compromises competitiveness of infant industries. The major risk of limited government intervention pointed out by Auty (1994*a*) as the main argument from institutionalists is deterrent pricing policies by existing firms. The rationale for advocating state support by institutionalists hinges on the fact that this will increase chances of success by entrants into the HCI sector and generate long-term financial gains (Auty, 1994*a*).

There seems to be an agreement among scholars like Owen (2012); Stiglitz *et al.* (2013) to the effect of suggesting that arguments raised by both neo-liberals and institutionalists are valid and crucial considerations for evaluation of policy options for policy-makers. The problem presented by this polarization of industrial policy controversy between neo-liberals and institutionalists is that methodologies selected to analyze industrial policy must objectively bridge this intellectual divide in order for objective policy options to be prescribed. In this regard, it would prove useful to make the case for how South Africa is employing industrial policy to advance industrial development in the various HCI sectors of the broader economy before discussing developmental pricing in the plastic industry.

2.6 Industrial policy landscape in South Africa

The industrial policy strategic focus, intent and goals in South Africa would not be complete without discussing how IPAP fits into the objectives of the current and previous macroeconomic policy framework and drawing some insights into resemblances to the WC. The current macroeconomic policy framework, the National Development Plan (NDP), has led to some revisions to the National Industrial Policy Framework (NIPF) and various iterations of the IPAP. The result has been an industrial growth focussed on beneficiation of natural resources, especially minerals. But the intention here is not to detail historical industrial policy in South Africa, but to acquaint the study with dynamics surrounding the various policy frameworks before developmental pricing. An in-depth discussion on historical aspects of macroeconomic policies in South Africa and their evaluation can be found in Haines (2015); Rustomjee and Hanival (2008); Banda *et al.* (2015).

The discussion will highlight the gradual shift of industrial and trade policy from the neo-liberal GEAR to a developmental state, or state-led industrialisation under NDP as summarised in Table 2.1.

Table 2.1: Summary of macroeconomic policy frameworks influencing industrial policy since 1994 in South Africa.

Timeline of macroeconomic policy frameworks since 1996		
Years implemented	Macroeconomic policy framework	Industrial policy influences, objectives and goals
1996 - 2004	Growth, Employment and Redistribution (GEAR)	Primary industry policy: Supply-side interventions to reduce unit costs, promoting vertical growth of value chains. SME and sectoral development. Human resource development enhancement: Special Programme for Industrial Innovation and Technology & Human Resources For Industry Programme. Trade policy: trade liberalisation, lowering tariffs to compensate depreciation, customs & excise restructuring, and expanding market access through WTO export facilitation and finance. Concessionary industrial finance: Procurement processes, investment promotion and coordination e.g Simplified Regional Industrial Development Programme to provide grants to SMEs or Small and Medium Enterprise Development Programme (SMEDP). Regional Industrial Development Programme (RIDP). Replacing industrial decentralisation with regional development corridors i.e Spatial Development Initiatives (SDIs)and Industrial Development Zone (IDZ).
2005 - 2009	Accelerated & Shared Growth Initiative for South Africa (ASGISA)	Developmental state focus. State investment favored to Public-Private-Partnerships (PPPs) for projects on industrial and infrastructure development. Skills development: Joint Initiative on Priority Skills Acquisition (JIPSA). Regional Industrial Development Strategy (RIDS) and associated Spatial Industrial Development Strategy. National Industrial Policy Framework (NIPF) and Industrial Policy Action Plan (IPAP)
2010 - present	New Growth Path (NGP)	Mixed economy and job creation in six priority areas; mining, manufacturing, agriculture, green economy, tourism and infrastructure development. Mining: Support for beneficiation downstream. Establishing a state-owned mining company focussed solely on beneficiation and enhancing exploitation of resources. Manufacturing: Re-industrialisation through improved performance by innovation and skills development and reducing input costs. Developmental trade policies to support exports and address unfair competition on local producers
2012 - present	National Development Plan (NDP)	2030 Developmental state strategy targets to eradicate poverty and reduce inequality, supplementing NGP objectives. Divesified economy, labour-absorptive growth. Reduce unemployment from 25% to 6% at 5.7 % annual GDP growth. Steps include: coordination and implementation of policy, infra-structure provision, competition law, reducing costs of business and improve efficiency of labour market. 15 Action Plans for structural and institutional reforms to achieve the targets including Economy & employment and Economic infrastructure e.g increasing the benefit of mineral resources.

Soon after the end of the apartheid era, in 1996, the new South African government forged a macroeconomic policy framework to inform industrial policy enshrined in the Growth, Employment and Redistribution (GEAR) framework. The strategy under GEAR was to provide resources for investment in social needs through the provision of the necessary resources, while at the same time overcoming trade barriers and liberalising flow of capital, akin to the WC. Other objectives were to lower inflation, stabilise exchange rates and to reduce fiscal deficits. The policy ran until 2005 and was replaced by the Accelerated & Shared Growth Initiative for South Africa (ASGISA) under which a more developmental state focus was initiated and refined through NGP, to result in NDP in subsequent years as discussed by Haines (2015). During the tenure of ASGISA, NIPF was formulated, culminating in IPAP in 2007. Prior to NDP, the NGP provided a transitional policy evolution from ASGISA into NDP to counteract failures by free market forces under GEAR to reduce unemployment, environmental impact and economic growth challenges. This is evident from continued adoption of some of the institutionalist policy objectives set out in the ASGISA and NGP during implementation of the NDP, while objectives set out under GEAR are being abandoned.

Unlike its predecessors, the NDP is not a policy document per se, but rather a set of national, strategic goals and targets to work towards achieving by 2030 for existing and forthcoming policies to fulfil the developmental state agenda set by ASGISA. The NDP embodies proposals to re-focus efforts towards labour-intensive industry promotion and improving export competitiveness with emphasis on increased government involvement in economic planning (Haines, 2015; National Planning Commission, 2013; Rustomjee and Hanival, 2008).

Since its inception, the IPAP has been a living document guided by NIPF strategic programmes. Haines (2015) argues that the IPAP has been refined to take a more focussed sectoral approach. Haines (2015) alleges that this has been done to redress opportunities lost at national level due to regional collaboration and industrial cooperation through broad-ranging strategies of SDIs initiated by GEAR.

The NIPF adopted by DTI (2007) is a variant of the macroeconomic strategy proposed by Amsden (2001) for NCIs to trade-off between risking wage cuts through import penetration and subsidising "learning" to enhance productivity growth. Similar to this approach, the DTI suggests that policy responses should address a cost-competitive production base, upgrading industry activities to higher value addition or beneficiation and economic inclusion of historically disadvantaged communities and regions as summarised in Fig 2.2.

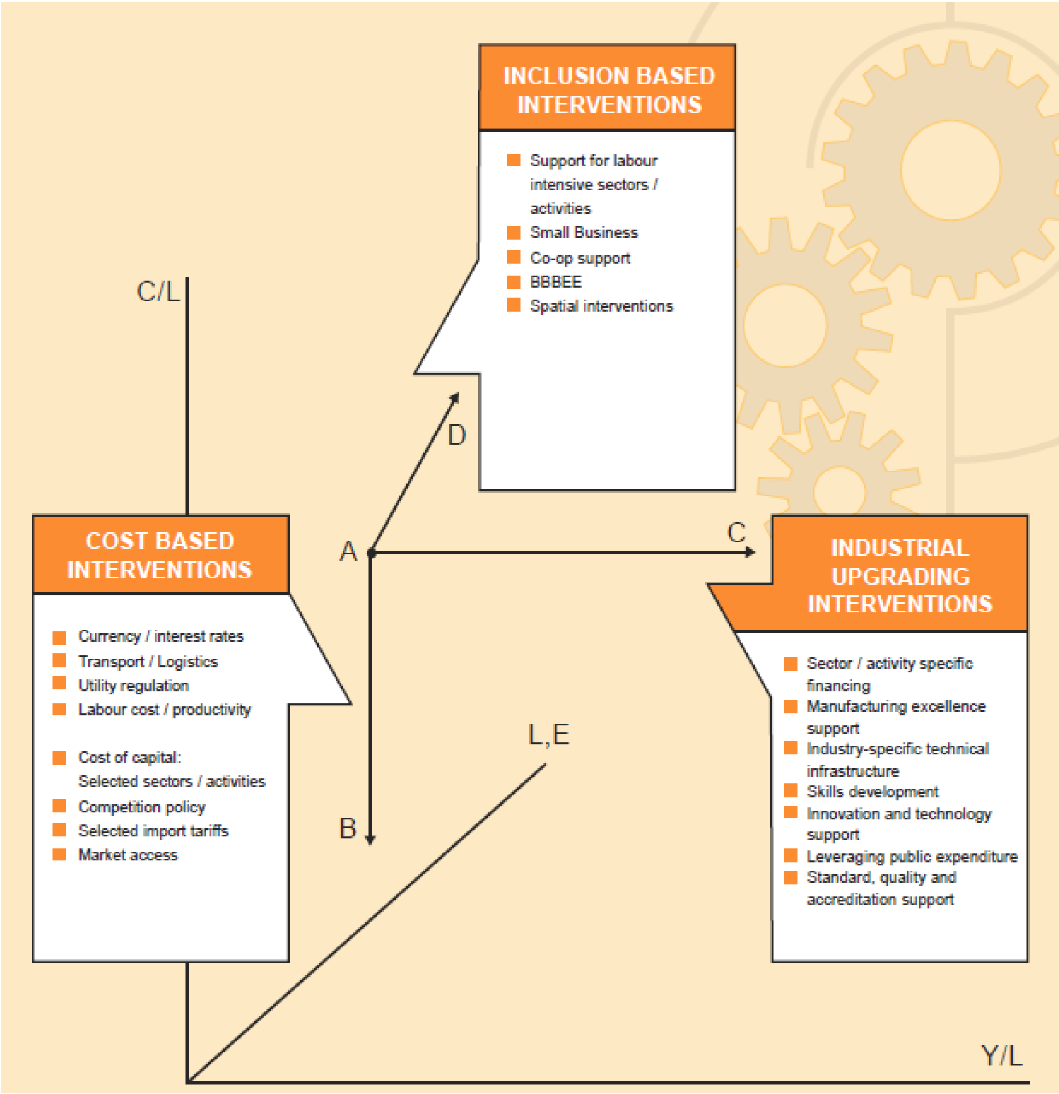


Figure 2.2: A summary of policy interventions proposed by NIPF. Source: DTI (2007); Amsden (2001).

Key:

A represents the "rest" of the less industrialised countries, D represents incumbent industrialised countries.

C is the cost per unit of production, L is the number of workers, E is the number of entrepreneurs and Y is the production output.

Y/L is the productivity and C/L is the real wage per worker.

According to Amsden (2001), governments of NICs can either do nothing and rely on market forces to lower wages through currency devaluation as imports out-compete local products, moving from A to B. Alternatively, NIC governments can intervene and increase productivity, a move from A to C. The NIPF framework proposes focus areas for intervention, which will not be discussed in detail or evaluated since this is beyond the scope of this study. The NIPF is presented here to introduce the broad South African government's industrial policy approach for discussions specific to IPAP and developmental pricing within the context of NGP and NDP.

In this regard, the NIPF, in line with the NDP's developmental state agenda, proposes 13 key strategic programmes for a range of interventionist industrial policies as summarised briefly as follows:

1. Sector Strategies which include "natural-resource based sectors, medium technology sectors (including downstream mineral beneficiation), advanced manufacturing sectors labour intensive sectors, tradable services sector".
2. Industrial Financing through an array of programmes for; sector-specific investment, industrial and infrastructure upgrading, innovation and technology, facilitating trade, SMEs and co-operatives.
3. Trade Policy based on sector-specific tariff reforms, upstream tariff reductions, export performance in value added products and export promotion, promoting foreign direct investment.
4. Skills and Education for Industrialisation.
5. Competition Policy and Regulation.
6. Leveraging Public Expenditure.
7. Industrial Upgrading, notably, the Manufacturing Excellence Programme (MEP) to support value chain upgrading at firm-level, as well as product and process upgrades.

8. Innovation and Technology.
9. Spatial and Industrial Infrastructure.
10. Finance and Services to Small Enterprises.
11. Leveraging Empowerment for Growth and Employment.
12. Regional and African Industrial and Trade Framework.
13. Coordination, Capacity and Organisation.

A discussion of these policy objectives is beyond the scope of this study, they have been stated here to position the focus of IPAP on the minerals value chains and beneficiation within their correct context of a broader downstream industrial development programme cross-cutting many industry sectors and government institutions. This inter-sectoral and inter-departmental stakeholder engagement has been demonstrated by the formulation of amendments to the MPRDA by DMR to the effect that some facets of developmental pricing policy would by domiciled in DTI, among other inter-ministerial programmes as shown in Appendix A, Fig A.1. Zarenda (2015) disputes the objectivity in centralisation of IPAP in the DTI, as opposed to across various government departments similar to NIPF. The DTI, however disagrees with that proposal since it finds it fitting to keep IPAP confined to the DTI in order to arrest industrial decline and support growth and diversification of the manufacturing sector (DTI, 2013, pp.6) and (Haines, 2015).

The details, perfomance and effectiveness of IPAP will not be discussed here, but for the purpose of this study, it will suffice to state that through IPAP, the DTI (2015) seeks to address barriers identified as constraints to growth in the plastics industry, which include;

> “. . . import parity pricing of polymers, electricity prices & reliability of supply, competition from imports, slow technological upgrading, logistics costs to distant markets and skills shortages.”

In order to combat these challenges, the DTI (2015) has instituted two major interventions, namely;

> "…development of a plastics production and innovation cluster, and promotion of the integration of plastics products in identified key sectors and cross-cutting areas."

At the same time, the Department of Mineral Resources (DMR) has proposed amendments in the Mineral and Petroleum Resources Development Amendment Bill (MPRDA) to the effect that certain quantities of mineral and petroleum products will be earmarked for beneficiation by DMR, in consultation with DTI, and all export of these products would require approval to ensure compliance with the beneficiation needs. As such, the minister responsible at DMR will prescribe a portion producers would be required to offer to to local beneficiators.

In addition, the DMR would also determine the price at which earmarked products shall be made available under the *developmental pricing conditions* as stated in the bill. According to the MPRDA bill proposed by the DMR (2013), developmental conditions would refer to:

> "…a pricing methodology of mineral/s, petroleum or mineral products, reserved for domestic beneficiation, as determined by the Minister."

However, no clarity or specific proposals have been put forward by DMR (2013) on pricing methodologies and principles that will be considered in this endeavor. This study proposes a simulation study as a suitable approach to analysing such a policy, using some insights from the "cost-plus 10%" *developmental pricing* methodology which was used in the steel industry since 2011 until the third quarter of 2016 when an alternative "basket price" methodology was proposed.

Chapter 3

Literature Review: Development of the global plastics industry

This chapter will start with a global overview of trends in the plastics industry and the various associated value chains in the plastics and polymer industry from the early inception of the industry in Section 3.2. In this regard, various technological developments and motivations for changes in choices of sources of raw materials (in Section 3.3), production processes (in Section 3.4) and current global trends (in Section 3.5). Section 3.6 will discuss some of the considerations and challenges policy-makers might be faced with in classifying plastics materials for regulation since polymer producers, plastic product manufacturers and end-users focus on different aspects when classifying and evaluating products. Section 3.7 will conclude the chapter by concentrating on some of the major considerations and trade-offs for companies involved in managing commodity value chains, such as plastics, with all the considerations discussed in mind.

3.1 Introduction

The growth of the plastics industry was facilitated by growth of the petrochemical industry in the 1930s, high plastics demand in the 1950s and internationalisation of plastics manufacturers that followed after the world war in 1960s. Recent developments have focussed on innovations to produce high performance plastics through advanced manufacturing and nanotechnology. Some of the developments currently shaping the plastics industry, but to a lesser extent, are focussing on bio-compatible polymers to address health and environmental concerns through the use of bio-polymers and renewable feedstocks such as biomass and waste.

The South African plastics industry is a strong participant in the global market. In order to understand dynamics in the industry from a global point of view, a historical global outlook of the industry will be undertaken. From a global perspective, the plastics industry as a heavy and chemical industry (HCI) has rapidly evolved over time. As an HCI candidate the DTI has prioritised for policy intervention, especially aimed at promoting infant firms, there are some considerations necessary for success of the policy. Some of the considerations can be identified from the development of the plastics industry, including raw material choice, cost and availability. Some of the trade-offs in raw material selection range from the cost of available technology to source and process the raw materials. This entails continuous investment, research and skills development to deliver the required technology. The ultimate goal has been to not only offer competitive prices, but to also achieve better performance and better returns to investors, while improving the quality of life for the society.

3.2 History of the global plastics industry

The use of the term “plastic” being broad and rather ambiguous, a comprehensive definition for the term “plastic” will not be possible without some historical context. A brief history of chemical developments of the most common materials will be outlined first to draw some conclusions about common features of which embody classification of materials as plastics. This will be done to provide better context for a discussion on developments and current trends in the plastic industry as discussed by Brydson (1999) and Patterson (2014).

Brydson (1999) attributes the birth of natural materials with the ability to flow to collective discoveries by Charles Goodyear and Thomas Hancock between 1820 and 1844 which culminated in production of hard rubber or ebonite, thereafter broadly termed plastics. Ebonite became the first commercial plastic material to be obtained through chemical modification of natural plastic. This development was followed by intense research by various commercial interests to make similar plastic material from natural products such as celluloid, gutta percha and casein plastics via different chemical processes. Further progress in plastics research resulted in the successful manufacture of synthetic plastics to substitute ebonite, namely, phenol-aldehyde plastics. This was made possible through techniques developed by Leo Hendrik Baekland to control and modify the 'phenol-aldehyde' reaction first reported by Adolf Bayer in 1872 and patented in 1899 by Arthur Smith. Celluloid was soon replaced by cellulose acetate as a non-inflammable alternative, due to improvements in processing technologies involving plasticizers in 1927. In this period, the plastic industry was heavily dependent on vegetable sources for raw materials, especially for cellulose, natural rubber and nylon (Brydson, 1999).

Modern discovery and major advances in technology to manufacture synthetic plastic material summarised in Appendix B.1 started with novel production techniques culminating in diversity of products with fine structure and versatile uses (Brydson, 1999). The first set of elaborate literature on experimental work to produce synthetic plastics reported by Patterson (2014) was published by Carothers titled "*An introduction to the general theory of condensation polymers*" in the *Journal of American Chemical Society* in 1929, followed by a handful of others from other scholars. This signalled the birth of modern commercial plastic materials which included polystyrene, poly(vinyl chloride) (PVC), polyolefins and poly(methyl methacrylates) (PMMA) which became commercially available between 1930 and 1940. Patterson (2014) and Brydson (1999) credit major contributions to the commercial production of plastic products mainly to private enterprises including a team of chemists led by I.G Faben at Dow Chemical Company for polystyrene development and production, I. Ostromislensky for PVC production, while and chemists at Imperial Chemical Industries (ICI) for discovery and production of polyethylene and PMMA or perspex.

3.3 Raw materials for plastic products

The period after World War II represented the golden era for development and growth of the plastic industry when a short supply of natural rubber was experienced, providing great opportunity for synthetic plastics to become very useful substitutes for natural rubber. This enabled great experience to be gained through extensive research of the chemical formation of synthetic plastics and their large-scale production, using cheaper operations. The result was the discovery of more synthetic plastics such as nylon and polytetrafluoroethylene (PTFE) by DuPont and Kinetic Chemical Inc respectively, including thermosetting resins such as polyester. This period witnessed great improvements in the quality and range of grades of plastics that resulted in commercial plastic materials, with the introduction of thermoplastics with unique properties (Brydson, 1999).

A more detailed history of plastics can be found in Brydson (1999) and Feldman (2008). The success of the plastic industry was a result of innovations by chemists to find economic ways to produce plastics from various raw materials, coupled with complementary innovative methods to process and compound the plastics into utility products by technologists. Other auxiliary professions that contributed to the success of the plastic industry are mathematicians, physicists, engineers, marketing and other experts in material. Mathematicians provided insights into interpreting physical data to assist in processing parameters. At the same time, engineers developed machinery able to process these materials, while new applications for the materials was sought after by sales experts with the help of designers (Brydson, 1999).

Successful synthesis and commercialisation of the thermoset resin phenol-formaldehyde (Bakelite) in 1907 and 1909 respectively, marked the beginning of the synthetic plastic industry. The first commercial synthetic thermoplastic polymer to be produced in large scale at low cost was low density polyethylene (LDPE) in 1933, which was manufactured by a free-radical polymerisation process in 1933 followed by a small-scale operation in 1937, and commercial production in 1939 (Brydson, 1999; Feldman, 2008).

According to Brydson (1999), the highest volume plastic material before WWII was *cellulosics*, which were produced from waste oat husks, while a major source for ethyl aclohol and ethylene to make polyethylene was obtained from sugar-cane molasses. As demand for plastics increased, new sources of raw materials had to be identified to maintain supply. The destructive distillation of coal had become the major source of raw materials for the manufacture of plastics production. Major products of coal distillation used as key raw materials for plastics production were coal tar and coke.

Coal tar was a source of aromatic chemicals used to make polystyrene, nylons and plastics from phenolic resins. Coke was reacted with calcium oxide followed by water treatment to obtain acetylene, which was used to make vinyl monomers for plastics such as PVC and polyacrylonitrile. This created great opportunities for research into ways to acquire monomers from petroleum, since a lot of hydrocarbon waste-products were being generated from production of fuels and solvents via ‘cracking’ petroleum by the oil industry.

‘Cracking’ processes, which had been invented between 1910 and 1920, involved the breaking down of petroleum fractions from high to lower molecular weight products such as gasoline. Most of the raw materials used to manufacture synthetic rubber (styrene and butadiene) during WWII were obtained from petroleum, as well as other chemicals including vinyl chloride, ethylene dichloride, ethylene glycol and ethylene oxide. This gave birth to the development and growth of the petrochemical industry, due to abandonment of coal and vegetable sources, in favour of petrochemical feedstocks to produce raw materials for plastics production. As a result, the global plastics industry in after the late 20th century has become heavily intertwined with the petrochemicals industry (Brydson, 1999; Feldman, 2008).

3.4 Production of plastics

Polymers are produced by polymerisation techniques which include variations of addition, condensation, step-growth, ionic and free-radical reaction techniques that will not be discussed here (Subramanian, 2015). The technique used to manufacture polymers has a large influence on the structure and properties of the polymer (feedstocks) to be used to make plastic materials. Monomers used to make polymers need to be highly pure, and usually either have two or more reactive, functional groups (condensation polymers) or at least a double bond (addition polymers) or are ringed. It is beyond the scope of this study to discuss polymerisation reactions used in the production of polymers for plastics in more detail, Odian (2004); Brydson (1999) and Subramanian (2015) can be consulted for in-depth information.

Commercialization of the plastic industry through the large-scale manufacture of polymers was made possible by polymerization technology improvements to allow better control over molecular mass of the polymer, the rate of the reaction, visco-elasticity of the polymer, amount of heat generated and structure of the polymer (including branching, stereo-regularity and cross-linking). The commercialisation of polymers as plastic products involved the utilization of different catalytic systems, especially chromium, Ziegler-Natta and *metallocene* catalysts, as well as optimising efficiency and operating costs of these systems. An example to illustrate the large-scale chemical production scheme for polymerisation of polypropylene is shown in Fig 3.1.

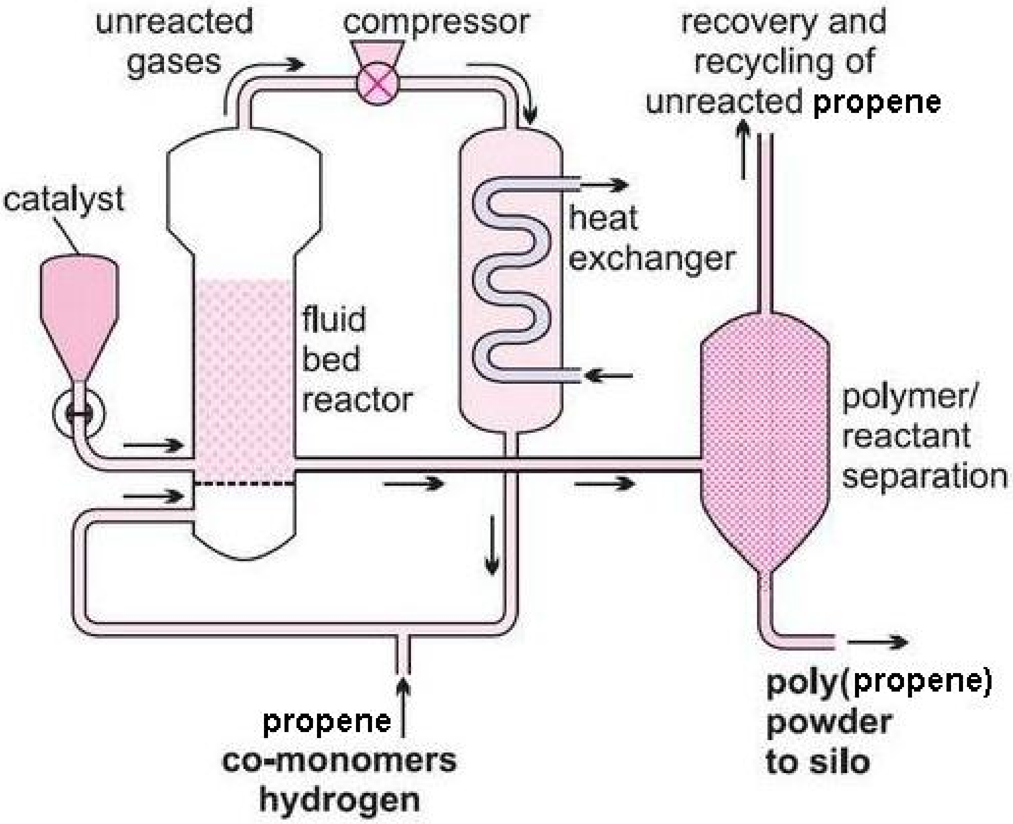


Figure 3.1: A simplified large scale production scheme for the polymerisation of polypropylene using Ziegler-Natta catalysts. Source: (University of York, 2014)

In these improvements, the catalyst system used governed the manner in which building blocks (monomers) and the growing chain approach each other during the reaction, making it possible to control and design specific polymers. Aspects of the polymer such as chain orientation (branches on same side or alternating), structure and properties became possible to manipulate and exploit to manufacture materials with unique, predetermined, physical characteristics and performance (Brydson, 1999). Demirors (2011) adds that these and other catalyst technologies that followed resulted in a broad diversity of polymerisation techniques and polymers with improved performance, requiring different processing technologies to obtain products suitable for a variety of applications.

The use of organometallic catalysts has resulted in many innovations to prevent catalyst "poisoning" by moisture, oxygen, carbon monoxide, carbon dioxide, sulfur compounds and water. The purity of monomers is usually required to be above 99% to prevent catalyst poisoning, coupled with cleanliness of the reaction tank. The most common process controls monitored for polymerization, which contribute the most to operating costs to obtain the desired product include flow rate, contents level, pressure and temperature. are critical to control in obtaining the desired polymer structure, reaction efficiency, reaction yield and molecular weight of the polymer (Subramanian, 2015).

3.5 Current global trends in plastic industry innovations

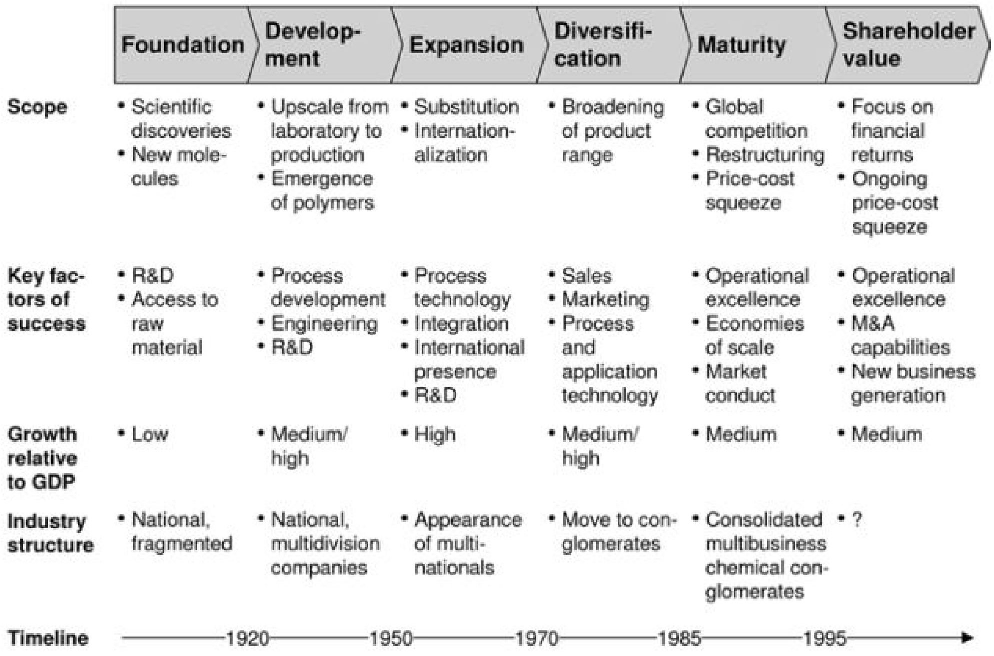
Currently, the plastic industry and its auxiliary chemical industries (especially polymers) are faced with a myriad of challenges and pressures from regulatory institutions and various interest groups. Some of the major concerns include environmental pollution, the need to conserve energy and health issues raised by use of polymers in biomedical applications and chemical leakage from food packaging.

The plastic industry is currently under pressure to rely less on petroleum for raw materials mainly for health and environmental concerns. The over-reliance of plastics on petroleum links the industry closely to suspected toxicity of petrochemicals used to make plastics and high prevalence of non-renewable plastic waste. For example, Europe introduced the '*polluter pays*' principle on producers and users of plastics materials in *The December 1994 EC directive on packaging and packaging waste (94/62/EC)*. This has resulted in major research in alternative sources of feedstocks away from non-renewables like petroleum to achieve lower pollution targets by companies and high *'recover and recycle'* activity to reduce plastic waste going to landfills. In addition, efforts to meet pollution targets have also contributed to all players in the plastics value chains to seek better technologies to reduce the amount of potential pollutants along the value chain, creating a big market for new technologies and polymers for plastic materials. Some of the alternative feedstocks rapidly gaining popularity with polymer manufacturers include natural gas, coal, waste biomass (straw grass and corn) and chemicals derived from processes involving biotechnology and micro-organisms.

According to Budde *et al.* (2006), bio-technology chemical sales were 5% of chemical sales in 2006 and projections indicated that advances in that industry would continue to reduce development time for bio-polymers, such that demand for bio-materials would diminish the global market share for conventional chemicals. Eyerer *et al.* (2010); Budde *et al.* (2006) project that the growth of the bio-materials industry will be aided by an increase in demand for biodegradable materials, as summarised in Appendix B.1. However, the IEA (2015*a*) estimated that natural gas contributed 19% to the chemical feedstock market in 2013, estimated to consume around 821 million tonnes (Mt) equivalent of energy sources, and no estimates were available for biofuels and waste. This competition from alternative feedstock will most likely have a great impact on margins realised in petrochemical value chains upstream in the plastic industry. Technology advances are also expected to enable polymer feedstocks from renewable sources to be available at much cheaper costs, further promoting growth of value chains involving renewable feedstocks.

Other examples of innovations currently shaping the plastics industry value chains which will not be discussed here include plastic strengthening techniques such as nanotechnology, 3D printing manufacturing and environmentally friendly products and practices. Other concerns being closely monitored, regulated and shaping the polymer and plastics industry include health and environmental issues associated with plastics including, compatibility with human tissue, toxicity of chemicals used and chemical waste (including effects on marine ecosystems), high water consumption for cleaning & cooling reactors, energy conservation and efficiency, discussed in detail by Eyerer *et al.* (2010); Bellù (2013) and Larson (2010).

According to Budde *et al.* (2006), the major drivers for the plastics industry, consistent with the chemical sector as a whole, have been discovery and process research and development (R&D), global expansion, proximity to raw materials and markets, economies of both scale and scope, diversity in products and services as summarised in Fig 3.2.



	Foundation	**Develop-ment**	**Expansion**	**Diversifi-cation**	**Maturity**	**Shareholder value**
Scope	• Scientific discoveries • New mole-cules	• Upscale from laboratory to production • Emergence of polymers	• Substitution • Internation-alization	• Broadening of product range	• Global competition • Restructuring • Price-cost squeeze	• Focus on financial returns • Ongoing price-cost squeeze
Key fac-tors of success	• R&D • Access to raw material	• Process development • Engineering • R&D	• Process technology • Integration • International presence • R&D	• Sales • Marketing • Process and application technology	• Operational excellence • Economies of scale • Market conduct	• Operational excellence • M&A capabilities • New business generation
Growth relative to GDP	• Low	• Medium/ high	• High	• Medium/ high	• Medium	• Medium
Industry structure	• National, fragmented	• National, multidivision companies	• Appearance of multi-nationals	• Move to con-glomerates	• Consolidated multibusiness chemical con-glomerates	• ?

Timeline ——1920——1950——1970——1985——1995——►

Figure 3.2: Major global growth characteristics in the plastic industry from inception to early 21st century. Source : (Budde *et al.*, 2006)

Budde *et al.* (2006) believes that the synthetic chemical industry, including plastics has reached maturity and is in the era of creating shareholder value through financial returns. Prior to this phase, firms have engaged in intense global competition as the industry's growth rate has been slowing down. Most firms became engaged in aggressive restructuring and cost controls through mergers and acquisitions to achieve operational excellence, resulting in a major shift towards consolidation of the industry and achievement of economies of scale which further enhanced cost synergies. Valencia (2013) agrees with these observations, but further suggests that long term cycles have dominated the industry, especially due to the global food and energy supply challenges, resulting in high feedstock costs. However, this could present an opportunity for the innovative flexibility of the chemical industry to craft solutions to combat greenhouse emissions and energy demand that could transition the industry into another "super-technology" growth cycle.

3.6 Classification of plastics

There are many different classification criteria used for plastics by manufacturers, technologists, designers and chemists. For purposes of this study, only thermoplastics, elastomers and thermosets will be considered due to the fact that the criteria has a strong link between physical properties and chemical properties. Besides thermoplastics, other polymers that can also be used to make plastics are regarded as either elastomers, thermosets or rubbers as summarised in Fig 3.3, regardless of how they are manufactured (Brydson, 1999; Eyerer *et al.*, 2010).

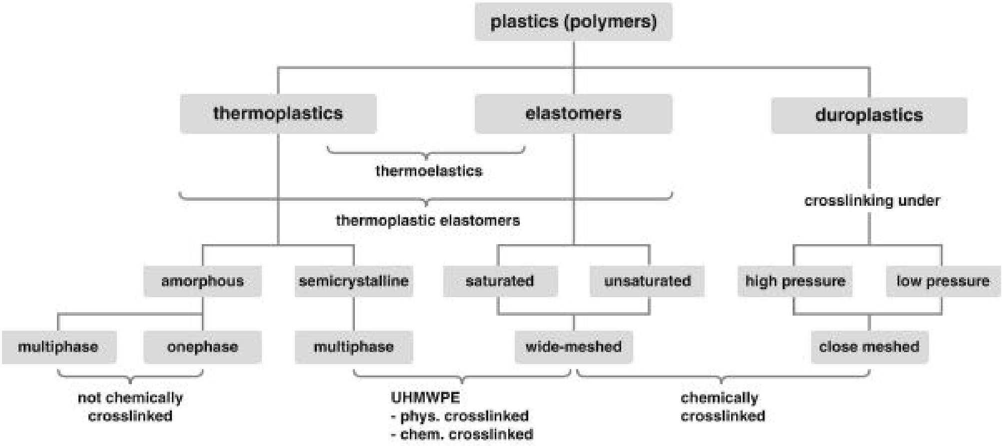


Figure 3.3: Classification of plastics. Source : (Eyerer *et al.*, 2010)

Plastics are polymers which exhibit visco-elastic rheological properties, or both elasticity and viscous flow when heated, rendering them *thermoplastics*, as explained by Mathias (2005) and Subramanian (2015). When plastics are heated and in the molten state, they are pliable (easy to shape and mold) into a wider variety of shapes compared to other materials such as steel and ceramics. The major difference between melt properties of plastics and other materials such as steel and ceramics is that plastics flow at much lower temperatures.

In the most general sense, plastics have become synonymous with materials capable of flowing from their solid state when subjected to heat. It is important to keep in mind that not all polymers can be used to manufacture plastic products, and even polymers used to make plastics do not melt or flow to the same extent or as easily as *thermoplastics*.

Special types of *elastomers* that exhibit plastic behaviour under specific conditions such as *thermoplastic elastomers* and *duroplastics* will now be discussed to highlight some of the problems that can be encountered by regulators when classifying plastics narrowly based on properties, final use or chemical composition alone.

Mathias (2005) notes that *thermoplastics* are those that can melt, while those that cannot melt are regarded as *thermosets* or *elastomers*. *Elastomers*, unlike plastics, can stretch when subjected to external stress, but return to their original state depending on the amount of applied stress. Plastics on the other hand, are much more difficult to stretch and become permanently deformed once they stretch, which makes them easier to mold and more desirable as products for daily use, as discussed by Mathias (2005).

Classification of plastics based on viscosity is motivated by the fact that equipment and process models used by process engineers monitor viscosity of chemical processes from production to processing technologies, as explained by Subramanian (2015). This classification is critical in determining what processing techniques, conditions and additives specific plastics require in order to manufacture different products with distinct properties using various polymer formulations. The processing technique and manufacturing conditions will ultimately confer physical properties that dictate final performance of the plastics in final products, aside from the chemical nature of the plastic material itself (Subramanian, 2015).

Brydson (1999) describes the underlying chemical property that renders thermosets unable to melt as the high degree of covalent cross-linkages between the macromolecular chains making up the polymer, resulting in an almost three-dimensional product, even difficult to recycle. The term thermoset polymer was derived from the fact that the polymer chains cross-link by forming covalent bonds under the influence of heat. Cross-linking can now be achieved using catalysts at room temperature, but the term thermoset has been retained for ease of describing the behaviour of these polymers.

In order to explain this behaviour of plastics, how hard and soft plastics can be obtained, another property of plastics termed *glass transition temperature* T_g will be briefly discussed. The T_g of a polymer, according to Mathias (2005) and Subramanian (2015), is the temperature at which a polymer changes from the semi-crystalline state (hard and glassy) to the amorphous state (soft and pliable), which has become central in modification of plastics and their exploitation for making useful products. Thermoplastics can be repeatedly melted to the viscous liquid state, processed, solidified by cooling and crystallised.Based on T_g; thermoplastics are regarded as amorphous polymers whose T_g is above room temperature and are therefore hard and glassy, while elastomers have low T_g, usually below room temperature and are therefore soft and rubbery. Mathias (2005) clarifies the use of the terms hard and soft when referring to plastics as simply plastics below or above their T_g, respectively, at room temperature.

Polymer properties like visco-elasticity, resistance to impact and deformation arise from the fact that polymer chains are able to re-arrange from disorderly, coiled structures (amorphous) to more orderly structures (crystaline) and various states in between when polymers melt, as shown in Fig 3.4.

The extend to which they remain coiled or uncoiled depends mostly on the chemical structure of the chains and processing conditions, especially shear rate and heating/cooling profile. The resulting chain structure imparts special properties to polymers such as flexibility, clarity (opacity and transparency), rigidity or stiffness. Appendix B.2 summarises the most common reactions used to produce polymers.

Physical and chemical modification of visco-elastic behaviour and other physical properties such as T_g and stress/strain modulus of plastics and other polymers which confer ease of processing, strength and usefulness of final products have become central to the design of polymers meant for use as plastics. The most important modification identified by Mathias (2005) and Eyerer *et al.* (2010) occurs during processing by mixing a polymer with additives called plasticisers to make the polymers flow more easily, more pliable and softer.

Another modification by polymer manufacturers is to combine two or more

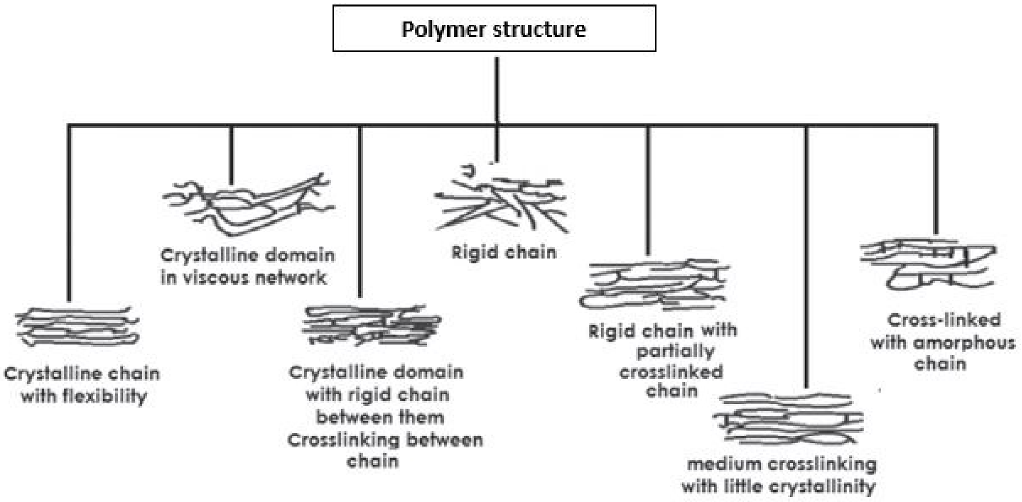


Figure 3.4: Polymer structure. Source : (Subramanian, 2015, p.19)

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types of monomers (co-monomers) with different structures and properties to make copolymers such as ionomers and block copolymers. When monomers with different properties are combined in this way, the polymer obtained would have temporary, reversible cross-links between sections of the polymer chains via non-covalent bonds like hydrogen bonds and ionic bonds to obtain *thermoplastic elastomers* or *thermoelastic* plastics as explained by Brydson (1999); Eyerer *et al.* (2010); Mathias (2005).

The co-polymer obtained will have superior strength and elasticity compared to the product that would have been obtained from reacting the individual monomers separately to obtain homopolymers. Strength and elasticity can also be improved by mixing inorganic fillers such as silica and glass, to the polymer product. Eyerer *et al.* (2010) recognises a separate class of elastomers called *duroplastics*, which cross-link during processing in the molding tool at higher temperatures above their T_g, usually 50°C compared to below °C for elastomers.

Other classifications of plastics found in literature are based on processing parameters, structure and intended use as already shown in Fig 3.4 and Fig B.2. For example, Feldman (2008) recognises the classification of plastic materials based on economic and application considerations into "commodity (high volume, low cost) and engineering plastics (higher cost and low volume)". Commodity plastics include poly(ethylene) (PE), poly(propylene) (PP) and poly(vinylchloride) (PVC), while engineering plastics include polycarbonates, polyimides and polyetherketone (PEK).

3.7 Value chain management in the HCIs and commodities industries

According to Kannegiesser *et al.* (2009), value-chains in the chemical industry are mainly associated with process, discrete and service industries. The chemical industry is a sub-industry of the process industry, which draws inputs from natural resources to the end consumer as illustrated in Fig 3.5

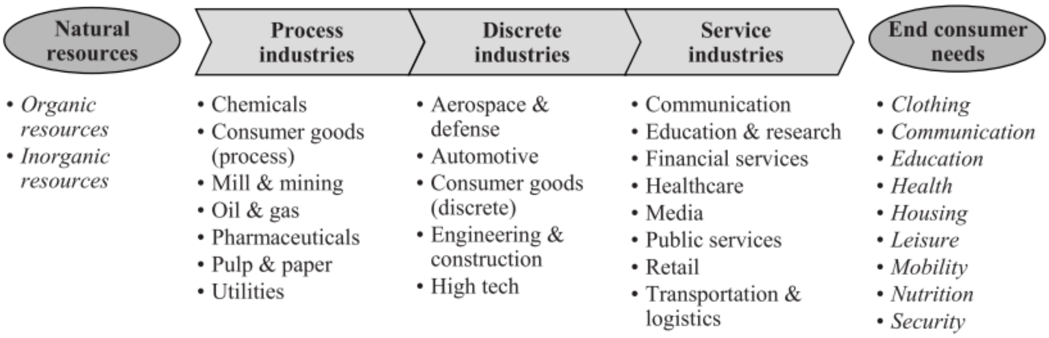

Figure 3.5: Chemical industry as part of process industry. Source: (Kannegiesser *et al.*, 2009, p.76)

Constituents of the process industry mainly include value-adding activities ranging from mixing, separating, forming and/or chemical reactions. The products of process industries are either intermediates or finished products used 'as is' or for production of other products (Kannegiesser, 2008; Kannegiesser *et al.*, 2009).

The discrete industry is characterised by use of specific components into discrete products for example in the automotive and engineering industry. The production in this instance is convergent since multiple input components use to assemble an individual product. The service sector is not characterised by physical production but rather multiple intangible services (Kannegiesser *et al.*, 2009).

The polymer industry is heavily reliant on petroleum-derived raw materials, which makes profits in this industry sensitive to volatility in production volumes, demand (sales) and supply related to volume and value as summarised in Fig 3.6.

Coordination of costs in the whole supply chain from inputs to sales in final products with respect to volumes and pricing in relation to value-added is a prerequisite for profitability as illustrated in Fig 3.6.

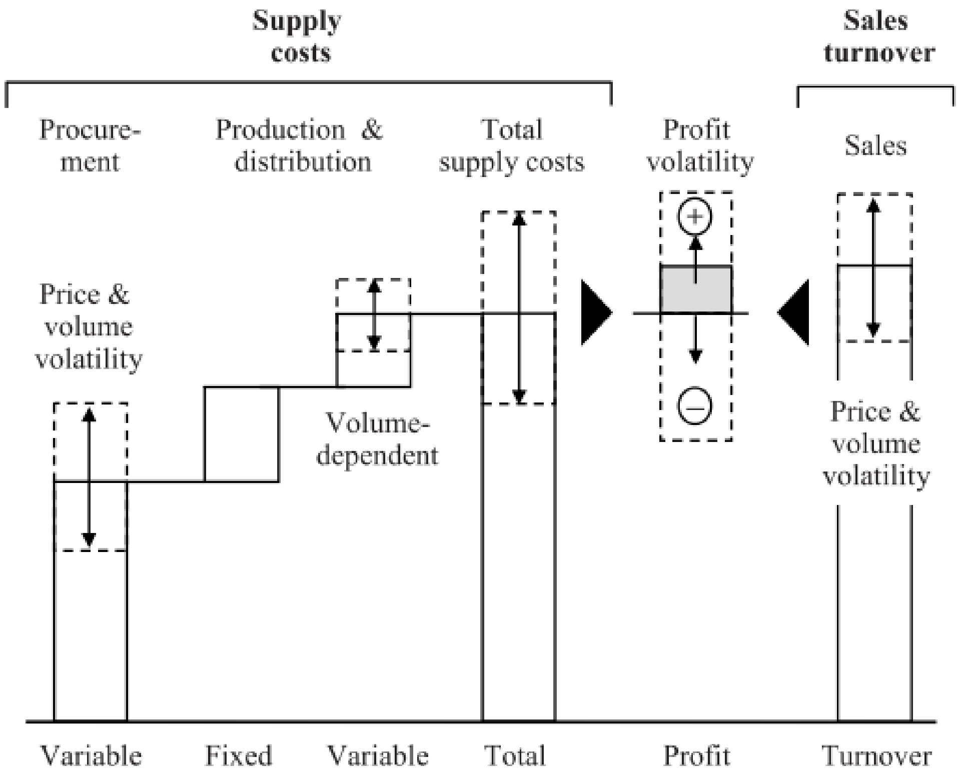

Figure 3.6: Volatility challenge on production and profits in commodity dependent value chains. Source: (Kannegiesser *et al.*, 2009)

Chapter 4

Literature review: Price regulation and industrial policy analysis

The cost-plus pricing policy evaluated in this study was observed in the steel industry, Section 4.1 will undertake a follow-up of the policy in order to draw some lessons to inform the current study with respect to the possibility of future applicability to the plastics industry. In Sections 4.2,4.3 and 4.4, developmental pricing, incentive regulation and cost-plus pricing regulation will be respectively discussed. Sections 4.2 will highlight some similarities between developmental pricing and margin squeeze or price squeeze regulation. This will be done in an effort to enable universal evaluation of price regulation focussed on increasing access to inputs by local downstream industries. Margin squeeze regulation will then be compared to incentive regulation as an alternative approach to increasing access to feedstocks by downstream industries and competitors. In Section 4.4, cost-plus pricing will be evaluated as the developmental pricing approach to be investigated in this study.

At this point, some tools used to analyse price regulation policies will be reviewed in Section 4.5, leading to the identification and selection of suitable tools to evaluate the impact of developmental pricing on the polypropylene upstream industry. Section 4.6 and Section 4.7 will respectively discuss cost classification and discounted cashflow approaches as components to evaluate the future attractiveness of the upstream polypropylene industry in a post-developmental pricing policy era.

4.1 Price cap regulation, reference and index pricing

The practice of reference pricing is a very common pricing mechanism used to benchmark product prices against an existing price external to the market or economic system in question, as noted by Bellù (2013) and Al-Sahlawi (2014). Other scholars also refer to this as index pricing or reference basket pricing, depending on the specific manner in which the external prices are selected or bundled as a benchmark. According to Al-Sahlawi (2014), the price charged by a producer is usually calculated by considering market forces such as a weighted average price based on the market share of products or producer price in the basket.

Commodity and utility-based industries have been observed to make use of this flexible, market responsive pricing approach. Some of the industries include; the oil industry, as reported by Al-Sahlawi (2014), the agriculture industry recorded by Ponte (2007)), as well as the pharmaceutical industry, as reported by Miraldo (2009) and Brekke *et al.* (2009). However, it was noted as early as the ‘80s by Tellis (1986) that reference pricing allows companies to charge high prices with their pricing models since their products will seem more attractive compared to highly priced alternative products chosen as the reference, prompting various policy proposals based on reference pricing in decades to follow.

The market responsiveness of reference pricing has led to its use as an alternative to rate of return (ROR) or cost-plus regulation, as discussed by Sappington and Weisman (2010). Bellù (2013); Currier (2011) point out that when used as a regulatory the basket of products used as a reference is selected on the basis of exogeno us price characteristics that best estimate the opportunity cost of producing or consuming that product. According to Bellù (2013), benchmarking can be against external prices from a basket of domestic prices for importable products, or an international basket of prices for exportable products. As pointed out by Currier (2011), the price cap will usually be a market based weighted average price of products in the basket plus a price constraint which limits the maximum price allowed for the product in question. The most common price cap level identified by Currier (2011) was an applicable producer or consumer price index (PPI or CPI) relevant to the products in the basket. Two main reference pricing rules discussed by Miraldo (2009) are; a minimum threshold reference price and a linear combination of company prices. Evidence from investigations by Miraldo (2009) suggests that compared to a minimum threshold policy, the linear combination policy might not be desirable since provides an opportunity for coordination to occur at higher prices.

According to Currier (2011) and Sappington and Weisman (2010), price cap regulation based on a reference price calculated from a basket of products and services has proven to yield better policy outcomes as a regulatory tool such as reducing industry costs, promoting competition and more efficient pricing. However, to date, this regulatory success has only been recorded in the service and utility industries ranging from telecommunications, postal services, airport services, natural gas, electricity , water and railway services and the pharmaceutical industry as reported by Miraldo (2009); Currier (2011); Brekke *et al.* (2009); Sappington and Weisman (2010).

Despite these successes, Bellù (2013) discusses some of the main problems related to reference pricing policy, especially the difficulty in establishing a common unit to measure variables such as monetary value in different currencies, the time value of money, inflationary price levels, transport costs, different societal purchasing power, societal values and other geo-political influences on prices observed by different markets.

There has been limited evidence from literature suggesting that there has been any reference price based regulation implemented in commodity-based, manufacturing industries. In South Africa, as early as 2006, the steel industry used a formula which takes an average price of local mills against a reference basket comprised of prices for the top 80% of steel consumers, and included producers in China, Germany, Russia and the United States of America. However, in early 2010, this practice was abandoned since there was a surge in iron ore prices which contributed to an escalation of production costs, in addition to higher trade barriers imposed by other steel producers as explained by AMSA (2015). After 2010, the steel industry experienced a brief period of cost-plus price regulation, with reported fears of negative effects on performance of the steel industry in South Africa (Roelf, 2016; Allix, 2015; DTI, 2016).

Recently, in August 2016, the DTI (2016) announced that an agreement had been reached with the steel industry on a reference pricing mechanism for all steel products using a basket pricing methodology. According to the DTI (2016), the price basket will be based on an 'import weighted' basket adjusted quarterly, comprised of countries South Africa competes with in specific downstream sectors, excluding China and Russia.The reference price will be calculated from a weighted average of domestic prices in countries from the EU, Asia and NAFTA including Brazil as shown in Table 4.1.

Table 4.1: Summary of countries included in the reference price basket for the steel industry and their respective weightings

Reference price basket and country import weighted averages			
Region	Regional import weighting	Countries	Import weighted average
European Union	50%	Germany	50%
		France, UK, Italy & Spain	50%
Asia	30%	Japan	50%
		South Africa & India	40 %
		Taiwan	10%
NAFTA & Brazil	20%	USA	75%
		Canada & Brazil	25 %

The forecast basket price applicable to this policy will be calculated from global steel price indices provided by the *CRU Group* and *MEPS (International) Ltd.* The policy will accommodate a one month forward 2.5% settlement discount to compensate for exchange rate fluctuations on the forecast basket reference price calculated from the import weighted basket, among other provisions. Downstream industries targetted to benefit from this policy are mainly those making fabricated metal products, machinery and equipment, vehicle and other transport equipment. The price to be charged for local steel products will realise a cap between 10 and 15% based on undisclosed market conditions agreed upon with steel producers in South Africa, discussed in detail by Roelf (2016) and DTI (2016).

A report prepared for FRIDGE (2010) by *Ozone Business Consulting (Pty) Ltd* to investigate upstream pricing for the chemical sector in South Africa suggested that reference pricing is practised in the polypropylene upstream industry. However, this finding did not receive support from any stakeholders during court proceedings that followed. Instead, there was widespread consensus that *import parity pricing* (IPP) was being used in the polypropylene industry, hence the need to regulate pricing practices as asserted by DTI (2015) and Jourdan (2014, p.20).

4.2 Developmental pricing approach

Walker and Jourdan (2003); DMR (2013) and Jourdan (2014)) assert that local mineral beneficiation will stimulate labor-absorbing downstream industries through increasing access to the country's natural resources. In the interest of that objective, the DTI (2015) and DMR (2013) have embarked on interventions to spearhead local beneficiation of resources in the mineral-energy complex (MEC). One of these interventions is the developmental pricing policy of feedstocks derived from petroleum intermediates in the polypropylene upstream industry being investigated in this study.

The beneficiation industrialization strategy is being championed by collaboration between the Department of Mineral Resources (DMR) and the DTI. The DMR has formulated long term strategies for beneficiation of minerals and petroleum products extracted locally to drive industrialisation. At the center of this strategy is a bill drafted by DMR proposing amendments to the Mineral and Petroleum Resources Development Act of 2002 (MRPDA) including introduction of a price regulation termed developmental pricing. At the time of writing, the bill is being revised by a select Committee for debate in Parliament (DMR, 2013). Similarly, the DTI's activities are being guided by a policy document called the Industrial Policy Action Plan (IPAP) that has identified key focus areas and interventions in various manufacturing sectors, including the chemical sector. As far as the beneficiation strategy is concerned, one of the aims of the proposed amendments to the MRPDA bill and IPAP is to address, among other things, upstream import parity pricing (IPP) practices. This is believed to result in increased access to raw materials for local beneficiation by downstream manufacturing industries (DMR, 2011, 2013; DTI, 2015).

Developmental pricing and margin squeeze regulation

According to Jourdan (2014) and DTI (2015), the South African upstream polymer industry is characterised by monopolistic firms with integrated operations involved in both upstream supply of essential inputs as well as downstream intermediates and products (DTI, 2015). Sarmento and Brandão (2007) and Tselekounis *et al.* (2009) note that industries dominated by such integrated monopolistic firms usually practice strategies commonly termed price squeeze or margin squeeze consistent with IPP practices alleged by DTI in the polymer industry.

Developmental pricing is mainly aimed at preventing effects of IPP by upstream companies on restricting access to raw materials by downstream industries in the South Africa's polymer industry, as alleged by DTI and DMR, consistent with margin squeeze regulation (Edwards, 2011; Nair *et al.*, 2014)). Stillman (2011), in defence of the South African steel industry summarises developmental pricing as a below-market price model that generates price levels below import parity and export parity price levels.

Margin squeeze strategies are mainly aimed at reducing downstream competition by intentionally raising costs for rival firms by charging exorbitant prices for inputs. In consideration of these principles and for the purpose of this study, developmental pricing will be treated as a 'price squeeze' or 'margin squeeze' regulation. The challenge faced by regulators is in choosing the appropriate method to test for the margin squeeze depending on the case at hand.

For example, the regulator can choose to use an integrated company's downstream operations as the 'equally efficient operator' (EEO) benchmark to evaluate the amount of protection afforded to competitors against excessive pricing by the integrated company. In such cases, the downstream competitor will only be protected from margin squeeze pricing if it is as equally efficient as the vertically integrated company, based on a comparison of the margins realized by the EEO and competitor.

Alternatively, the regulator can benchmark the pricing levels charged to competitors by the integrated company by evaluating the margins realized by a 'reasonably efficient operator' (REO) downstream. In this case, prices charged to the REO must yield comparable margins to margins between the integrated company's upstream and downstream prices, after due consideration of costs incurred by the REO downstream competitor.

A comparison of these two approaches is illustrated in Fig 4.1 to demonstrate how both approaches would not get the same results for a margin squeeze test.

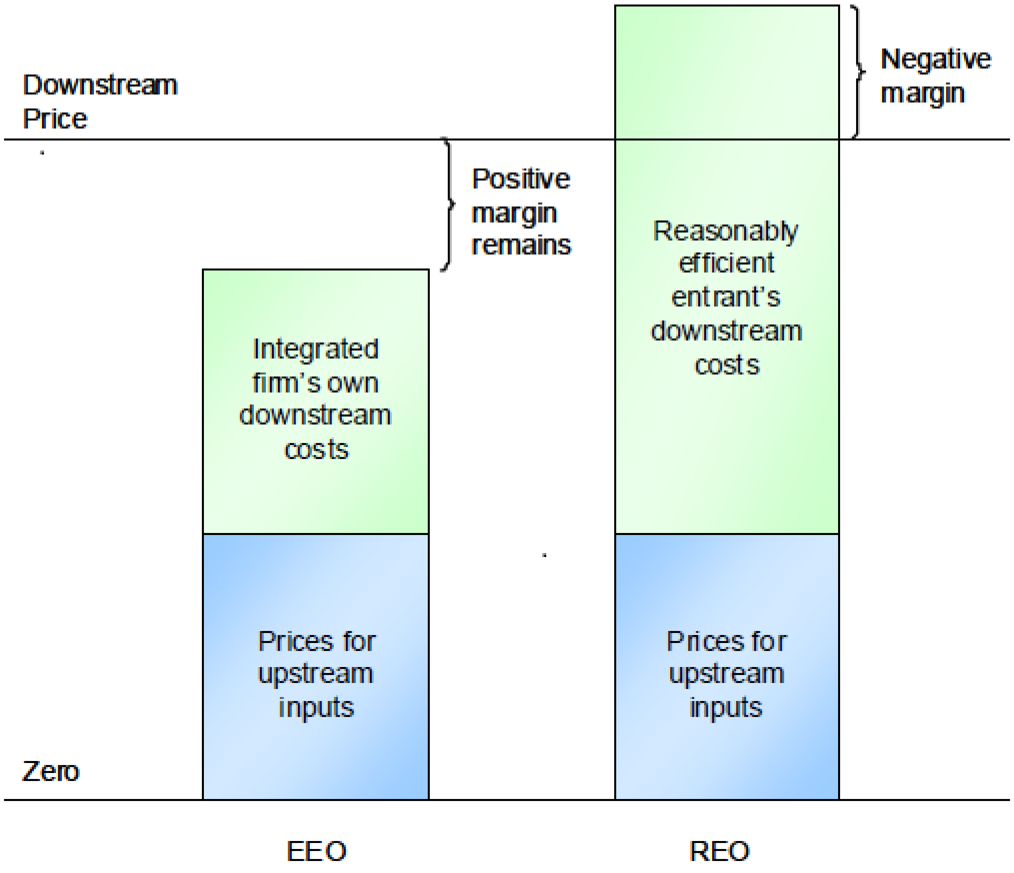

Figure 4.1: Margin squeeze pricing strategy by incumbent. Source : Edwards (2011)

Fig 4.1 summarizes how testing for margin squeeze using the EEO standard would deny protection to the competitor, while the integrated company would be non-compliant using the REO approach despite its cost advantages. An in-depth discussion on the economic and competition law considerations for margin-squeeze regulation are dealt with in Bender and Götz (2010); Edwards (2011); Jullien *et al.* (2013); Hou (2014) and Banda *et al.* (2015).

Sarmento and Brandão (2007); Tselekounis *et al.* (2009) and Banda *et al.* (2015) are in agreement that when effectively enforced, margin squeeze regulation increases access to inputs downstream and determines acceptable profit levels for the monopolistic firm at all stages in the value chain. The OECD (2009) discusses margin squeeze in more detail, especially how it is being enforced by regulators in its various jurisdictions, including legality, challenges in investigations, limitations and alternative regulation to address these challenges.

However, Sarmento and Brandão (2007) briefly outlines some considerations for different levels of margin squeeze regulation. The first being that a tight price regulation might reduce the incentive for the monopolistic firm's incentive to improve the quality and development of the market. Secondly, when too low, price regulation might result in inefficient entry of new companies thereby failing to create sufficient competition important for the market to deliver high quality products at low cost. When price regulation is too high, entrants might be incentivised to build inefficient facilities to bypass the incumbent. As a result, Sarmento and Brandão (2007) suggests that margin squeeze regulation can be a trade-off between enhancing competition downstream and promoting investment in the market quality.

4.3 Incentive regulation

In order to curtail the lack of incentive to reduce costs and improve the quality and development of the market in a price regulated environment, various scholars have proposed a number of possible "incentive regulation" mechanisms, also termed earnings sharing regulation (ESR) by Sappington and Weisman (2010).

As explained by Jacobzone (2014), on behalf of the OECD Secretariat, the principle of incentive regulation is that this approach aims to facilitate the reduction of prices by providing incentives that reward regulated companies for minimising cost, adjusted on an annual basis as illustrated in Appendix C.1 and Appendix C.2.

An example of such an approach was operationalised by the *Laffont-Tirole model of regulation.* The model mainly addressed the problem encountered with cost-based mechanisms stemming from the regulator only observing production costs. The model attempts to solve the information problem by assuming two scenarios, before and after the policy. Before the policy, the company is perceived to have more information than the regulator on its technology's ability to reduce costs. Whereas, after the policy, the regulator will only observe production costs realised by the effort and not how much was spent by the company to reduce these costs (Tirole, 2014).

However, these regulatory methodologies have mostly been successfully implemented in service industries, including the transport industry, electricity and energy generation, telecommunications as well as other manufacturing industries such as tobacco, and to a greater extend, environmental regulation (Giannakis *et al.*, 2005; Jacobzone, 2014; Sappington and Weisman, 2010). Giannakis *et al.* (2005) did not find any evidence suggesting that short-term benefits dominated strategic behaviour for regulated utility companies in the United Kingdom. This observation was also observed by Giannakis *et al.* (2005) and Jacobzone (2014), adding that incentive regulation demonstrated greater benefits as it integrates service quality into benchmarks, compared to regulations only based on cost.

4.4 Cost-plus pricing methodology

Various other margin squeeze regulation are practised including retail-minus pricing, but this study will only analyse cost-plus pricing methodology, also known as rate-of-return (ROR) regulation, which is based on calculating cost per unit produced, as suggested by Sarmento and Brandão (2007); Klump (2012); Dolgui and Proth (2010). Cost-plus pricing methodology has already been implemented to some extend in the South African steel industry. The *Economic Sciences Prize Committee of the Royal Swedish Academy of Sciences* in its review of Tirole (2014) and Jacobzone (2014) observes a variant of this called cost-plus-ROR. This approach allows the regulated monopoly to charge prices in excess of marginal cost, with a cap on the ROR. When practised voluntarily at firm level, the margin depends on a variety of factors including; market, labour, competition intensity, competitors price, company size, intangibles (value-add services) and the industry in question, a suggested by Guilding *et al.* (2005); Dolgui and Proth (2010); Klump (2012); Vohra and Krishnamurthi (2011).

However, when enforced as a price regulatory mechanism, the regulator allocates cost components to which a fraction of the cost of the investment is added, for example a marginal cost formula called efficient component pricing rule (ECPR) (Sarmento and Brandão, 2007; Edwards, 2011; Stillman, 2011). The ECPR, as summarised by Sarmento and Brandão (2007), assumes that the input price is equal to marginal cost of providing inputs plus the incumbent's lost profit in the retail market as a result of supplying the inputs to rival firms (Sarmento and Brandão, 2007; Tselekounis *et al.*, 2009; Matsumura and Matsushima; Jullien *et al.*, 2013). However, due to this competitor limitation and the unavailability of sufficient information on the cost structures for the industry under study to attempt its application, this pricing methodology was not investigated further.

The major advantages of cost-plus pricing identified by Vohra and Krishnamurthi (2011) and Dolgui and Proth (2010) include the fact that it is simpler to calculate total cost and the price than customer value, the price is easy to manage and that it stabilises the market (Dolgui and Proth, 2010; Vohra and Krishnamurthi, 2011). Another advantage identified by Jacobzone (2014) is that despite regulation, the companies are allowed to cover operating costs, in addition to additional income on capital spent. In some cases, the regulation might allow prices to be adjusted to reverse excess gains or to compensate losses that might be excess (Jacobzone, 2014).

On the other hand, cost-plus pricing methodologies have been found to face some enforcement challenges in addition to normative shortcomings. The most important of these is the information problem, since this regulatory tool not only relies on information, but constant monitoring to gather current and accurate information, as asserted by Tirole (2014). This problem is encountered where information asymmetry is high, where the regulator cannot accurately quantify or determine whether any effort is being directed at reducing production costs or to upgrade production quality by regulated firms. In these cases, Tirole (2014) predicted that even with a subsidy, if the regulation is not robust enough, it could either lead to overruns in cost or poor growth in production.

Secondly, the cost allocation problem, where the regulator has difficulty in estimating the allocated cost per unit produced from the fixed cost component per unit. Thirdly, price regulation based on price would offer the firm no incentive to reduce production costs. Lastly, the mechanism might also encourage the firm to invest more in capital projects compared to other inputs (Tirole, 2014). Moreover, because cost-plus pricing ignores the demand curve (price elasticity) since it does not consider the bahavior of customers, competitors and other market behaviours in relation to the price, it might result in sub-optimal pricing (Dolgui and Proth, 2010; Vohra and Krishnamurthi, 2011). By ignoring supply and demand dynamics, sales volumes cannot be predicted accurately (i.e elasticity of demand). Since realised sales volumes depend on price of the product (demand), high prices might push demand down and low sales volumes will be achieved. This results in allocated fixed cost per units sold to go up and a higher price will be required to cover future low sales volumes (Vohra and Krishnamurthi, 2011).

Matsumura and Matsushima also suggests that another cost allocation problem is that firms will be motivated to influence the regulated input price by manipulating the costs. (Matsumura and Matsushima), however points out that this problem might be less applicable if a neutral regulator determines the rule for calculating the price in price regulation, leaving little room for manipulation.

The third problem of cost-plus pricing regulation is encountered in the case where a company produces many products and the fact that it ignores opportunity cost considerations (Dolgui and Proth, 2010; Vohra and Krishnamurthi, 2011), which ties in with the cost allocation problem and the information problem. Vohra and Krishnamurthi (2011) observes that fixed cost allocation in multi-product cases is difficult since cost-plus pricing might be inaccurate in allocating fixed costs among the units sold which may mislead profitable pricing opportunity. This cost allocation problem is also discussed in detail by OECD (2006). In essence, OECD (2006) articulated this problem as applied to the telecommunications industry, outlining how sunk costs incurred to provide the service would need to be amortised in order to allocate a meaningful cost for the costs in purchasing the asset. The OECD (2006) proposed the use of original or historical costs and depreciated replacement cost approaches to resolve cost allocation problem, but there was not sufficient support from literature supporting use of this approach in heavy and chemical industries.

Other problems of cost-based pricing regulation are related to the lack of “normative justification” for optimal regulation to be selected, an example being criteria to ascertain politically acceptable rates of return to be instituted by the regulator (Tirole, 2014).

The approach considered in this study is the one proposed by Stillman (2011), where the *cost-plus price* model assumes that inputs constitute the largest share of costs (Stillman, 2011). In this case, as described by Vohra and Krishnamurthi (2011) and Klump (2012), the cost-plus pricing regulation test will involve adding a mark-up or margin to the total costs, to include both fixed and incremental cost, .

4.5 Approaches to analysis of price regulation policy

At commencement of this study, there was limited literature focussing on value chain analysis approaches as applied to industrial policy analysis in South Africa. However, value chain analysis is common practice by international development organisations and other regional economic bodies as demonstrated by studies documented by Schmitz (2005); Humphrey (2004); Springer-Heinze (2008); Mathias L. Herr and Muzira (2009); UNIDO (2009); D’Adamo (2014). This chapter will begin by briefly discussing other methods identified in literature to be suitable for quantitative industrial policy analysis. Covered in this section is game theory (Section 4.5.1), accounting and statistical methods (Section 4.5.2), but these won’t be discussed in detail. The rest of this section will then be dedicated to a more in-depth discussion on value chain approaches to policy analysis (Section 4.5.3), especially global value chain, followed by simulation studies (Section 4.5.4) and scenario-based models (Section 4.5.5).

4.5.1 Game theory approaches

One of the major consequences of margin squeeze regulation observed by Sarmento and Brandão (2007) and Tselekounis *et al.* (2009) is that while regulators set prices to maximize social welfare, firms respond by adjusting production levels to maximise profit (Sarmento and Brandão, 2007; Tselekounis *et al.*, 2009). This has led most scholars to treat margin squeeze regulation as a competition game suitable for analysis by differential game approaches since strategic interactions among actors will take place over time as argued by Elgar (2012).

Game theory attempts to simulate strategic behaviour in game situations mathematically for example cooperation for loss and cost allocation (Shaloudegi *et al.*, 2012). These approaches are discussed in detail by Elgar (2012) including Bertrand, Cournot, Stackelberg and ECPR competition models to analyse price and quantity competition and will not be discussed in detail in this study. As discussed by Elgar (2012), differential and static game approaches to model industrial organisation situations are limited to firm level policy analysis and is not applicable to value chain level evaluation. Even at firm level, game approaches to policy analysis are compromised by over-dependence on assumptions made to use either the static or dynamic model. Assumptions made to determine the competition regime being employed for market allocation might become irrelevant as capacity changes over time in parts of the oligopolistic firms (Sarmento and Brandão, 2007; Tselekounis *et al.*, 2009; Elgar, 2012; Matsumura and Matsushima; Jullien *et al.*, 2013)..

4.5.2 Accounting and Statistical models

Other scholars have used mathematical, statistical, accounting models and scenario-based models to evaluate policy effects on various aspects of industrial development interventions. Multiple linear regression models were used by Wang (2013) to determine the extent of Small and Medium Enterprises (SME) development. Wang (2013) used statistical models based on Ordinary Least Square (OLS) method to estimate determinants of development (Wang, 2013). Wang (2013) approaches determinants of growth, specifically focused on SMEs in terms of revenue growth and net profit growth using multiple linear regression. Models based on accounting frameworks are usually sum differences between input costs and production cost and production quantities to evaluate margin changes for policy analysis and are based on more complete information as demonstrated by Bellù (2013); Zwan and Nel (2010).

Bellù (2013) found that using accounting models was better suitable to investigate causal links between policy changes to relationships between yields and output, output and revenue, revenue and value added, value-added and margins for each actor at each segment of the chosen value chain. Bellù

(2013) further justifies choosing an accounting model since it not only identifies and quantifies causal links for policy changes, but enables investigation of the 'cause-effect-cascade' in the value chain. In this sense, links can be systematically analysed between yields, outputs, technical coefficients, prices, profits, scale factors and other variables affected by the policy. Accounting frameworks, unlike game-based approaches allow economic analysis at market prices as cost-benefit analysis of each agent, especially opportunity costs, are considered. This is possible since net benefits from one activity can be easily compared to cost of foregone revenues accruing from alternative uses of inputs/factors of production, as well as the benefits stemming from producing rather than buying the same products. Examples of accounting approaches in this framework suggested by Bellù (2013) include activity accounts such as production accounts and income account approaches.

4.5.3 Value-chain frameworks

The value chain concept describes all activities and the various phases of production involved in transforming the inputs from the supply stage until the final product reaches the market UNIDO (2009). Value chain frameworks allow simplification of these complex, interlinked activities to allow policy makers and other chain development practitioners to understand how the chains work, so as to increase the impact of interventions (UNIDO, 2009). The value chain framework therefore enables policymakers and industrial development practitioners to identify bottlenecks and leverage points required to optimise coordination between different chain operators in the value chain. This is very crucial because value chains evolve to adapt to requirements of the various operators.

The advent of globalisation means that local producers and operators are no longer heavily reliant on established market channels. On one hand, participation of developing countries in global value chains through export-oriented economic development strategies expands market channels. On the other hand, it requires regular upgrading of local value chains in order to improve coordination of activities to effectively and competitively capture maximum value from these chains (Gereffi *et al.*, 2005; Gereffi, 2014).

The Global value chain framework

Globalisation and international trade have presented a new challenge to formulation and analysis of industrial policies for industrialisation of developing countries. According to Serra *et al.* (2008), a majority of industrialisation strategies in developing countries have been stylised around the Washington Consensus which popularised adoption of export-oriented industrialisation strategies and more liberal economies. The success of this policy paradigm has been strongly contested by development organisations and economic scholars around the world arguing that it has achieved little or no economic growth in most developing countries, especially in sub-Saharan Africa as observed by Gore (2000); Serra *et al.* (2008); Babb (2013); Gereffi (2014); Priewe (2015). One of the debates raised by the "transnational policy paradigm" is whether traditional policy analytical frameworks and tools are effective in capturing all activities targeted at economic growth for developing countries in the global economic order post-Washington consensus (Gore, 2000; Gereffi *et al.*, 2005; Cattaneo *et al.*, 2010; Barrientos *et al.*, 2011). In particular, analytical tools are being sought to appraise industrial policies and regulation aimed at economic growth in a globalised economy responsive to dynamics from supply-oriented to demand-oriented economic activities. Such an approach would be attentive to policy analysis on access to inputs for production, such as feedstocks, skills, technology and credit as well as on buyers of the outputs (Schmitz, 2005).

A Global Value Chain (GVC) framework was developed in the last decade by a group of researchers from inter-disciplinary and international groups in an attempt to address insufficiencies of current supply-oriented policy analytical frameworks. The major advantage of GVC on industrial development in the globalisation era is that it addresses implications of global trade on both corporations and governments by examining economic activities of global industries from both the top down and the bottom up (Gereffi, 2014; Gore, 2000; Gereffi *et al.*, 2005; Gibbon *et al.*, 2008; Cattaneo *et al.*, 2010; Gereffi, 2011).

Globalisation and consequent emergence of GVCs has resulted in the need for development strategies by developing and developed countries alike, to focus on integration of local industries into the global economy (Gereffi, 2011). According to Gereffi (2011), the GVC framework is capable of examining the structure and dynamics of the different participants in a single industry, regardless of geographic dispersion of activities, simultaneously for both developed and developing countries. This makes GVC frameworks suitable for evaluating and identifying industrial policy interventions to improve competitiveness and value capture from insertion of local industries into GVCs accompanied by social and economic development Gereffi (2011).

The GVC framework as described by Gereffi (2011), traces value added sequentially in an industry from “conception to production and end use”. This framework provides a holistic view of global industries using both the top-down and bottom-up approaches. It accomplishes this by examining the job markets, technologies, regulations, products, processes and markets for the specific industry in all the geographic locations concerned. This paradigm in policy analysis is a useful tool for policy makers to solve some of the development problems not addressed by other tools.

Most importantly, the role of emerging economies is identified by the GVC framework as drivers of growth, while acknowledging how certification of products and processes in these chains guarantees competitiveness for export-oriented economies, especially private regulations and standards. This is unique because GVCs are prone to national and international political limitations not covered by other tools. It is also possible to assess social and environmental development concerns to formulate development initiatives to adapt economies to these demand-driven chains for dynamic economic upgrading (Gereffi, 2011).

Global value chain analysis

The GVC is a value chain that describes all activities involved in transforming a concept to a product until it reaches the end-user and beyond. Unlike traditional value chains which only focus on activities carried out in one firm or divided among different firms in local industries, the GVC includes activities in value chains in inter-firm networks on a global scale. Analysis of GVCs focuses on both tangible and intangible value-adding activities in global industries, thereby allowing a holistic view from both the top-down and bottom-up (Gereffi, 2014). Gereffi (2014) identifies the top-down approach as a “governance” of lead firms and the organisation of global industries. The “governance” of GVC allows identification and analysis of actors exercising corporate power, which has the power to shape profit and risk distribution in an industry. As an example, examination of how lead firms govern their global-scale affiliate and supplier networks falls under this approach.

In contrast, the bottom-up approach includes “upgrading” activities such as strategies to maintain or improve position in the global economy by countries, regions and economic stakeholders. GVC analysis using the “upgrading” concept address on whether economic gains from participation in GVC result in stable employment, labour conditions and other social downgrading. Economic upgrading as defined by Gereffi (2014), is the process by which economic actors move from low to high value activities in GVCs. The four main categories of upgrading identified by Gereffi (2014) are product, process, functional and chain upgrading activities, and will not be discussed here (Gereffi, 2014). An example outlined by Gereffi (2011) is “how business decisions affect trajectories of economic and social upgrades or downgrades in specific countries and regions”.

Dimensions of Global Value Chain dimensions

The four basic dimensions of the GVC framework discussed by Gereffi (2011) are the input-output structure, geographical consideration, governance structure and institutional context as summarised in Table 4.2.

The GVC framework covers a broad range of development objectives such as economic and social competitiveness, as well as environmental aspects. New areas like labour regulation, workforce development and greening of value chains are being explored (Gereffi, 2011).

According to Gereffi *et al.* (2005), governance structures are determined by three main factors, namely information complexity, information codification and supplier capability to satisfy all the requirements for a specific transaction. Sustaining transactions in GVCs requires suppliers to constantly get sufficient information knowledge on specifications for products an processes involved. The complexity of this information and knowledge influences the extent it is codified and transmitted efficiently along the value chain without requiring further investments. All these prerequisites determine whether or not a supplier will have capabilities to acquire or sustain old and new transactions. This interaction between suppliers, buyers and consumers results in different

Table 4.2: A summary of the four basic dimensions of the GVC framework

The GVC framework	
GVC dimension	Description and main activities
Input-output	How raw materials are transformed into final products Identifies main, industry specific activities in the GVC, industry organisation and industry historical trends. Characterisation of companies in the value chain with respect to size, stakeholders and territorial market share.
Geographic scope	Lead firms are identified for each tier in the value chain. The country/regional-level positions of lead firms in certain countries and their level in value chains determined. What factors affect globalisation of value chain in a specific industry. Mapping shifts in global industries.
Governance	Relationships based on power and authority that dictate the flow and allocation of resources (i.e human, material and financial resources. Defines control and coordination dynamics of the value chain.
Institutional context	Describes how the impact of domestic and global policies, and economic conditions shape globalisation in the various tiers of the value chain. Comparison of different countries' value chains.

governance structures for global value chains identified by Gereffi *et al.* (2005) as depicted in Fig 4.2.

The five main types of governance structures include market, modular, relational, captive and hierarchy structure. Based on preliminary knowledge of the polypropylene industry in South Africa and for purposes of this study, main characteristics of the hierarchy structure will be briefly discussed.

Gereffi *et al.* (2005) explains that hierarchy structures result from unavailability of competent suppliers in the value chain due to product complexity. Specifications for such products cannot be codified, this results in lead firms developing capacity for in-house production. Kaplinsky (2013) and Gereffi *et al.* (2005) assert that this makes it easy to transfer and exchange knowledge along activities in the value chain, since participation is not restricted by a variety of standards. In addition to this, it is more efficient to coordinate inputs and outputs, resources and control intellectual property. Kaplinsky (2013) adds that the hierarchy structure is characteristic of companies with

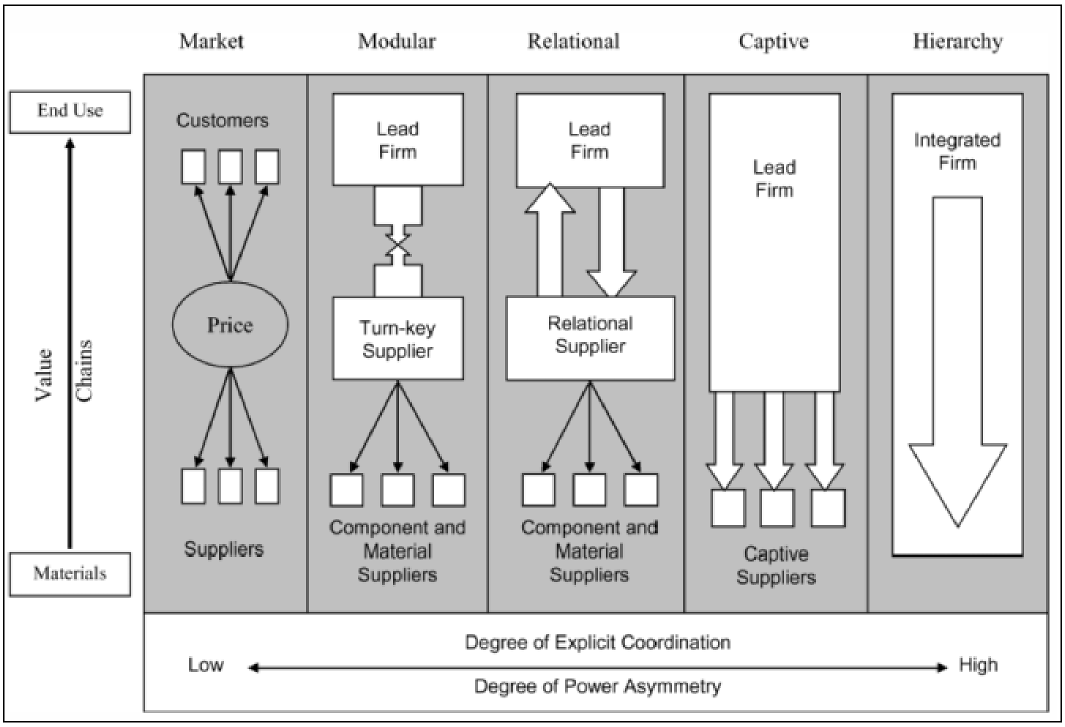

Figure 4.2: Five GVC governance types. Source: (Gereffi *et al.*, 2005)

core technologies, enabling them to exercise control by cascading requirements from the top to the bottom in the value chain. As a result, the degrees of coordination and power asymmetry in value chains with integrated lead firms are both high.

4.5.4 Simulation approaches

Shereih (2015) explains that simulation modelling techniques are useful problem solving approaches which experiment on real-life situations or systems by representing the behaviour of the system with a model. Various studies have demonstrated the usefulness of simulation to account for risks and uncertainty involved in petroleum industry related activities including planning and exploration (Shereih, 2015; Al-Attar and Alomair, 2005), financial planning and decision analysis (Al-Sahlawi, 2014, p.162-183), and supply chain optimisation (Carneiro *et al.*, 2010; Al-Othman *et al.*, 2008; Ferreira and Trierweiler, 2009). Policy analysis simulation models have also been widely used as demonstrated by Glickman (2014); Dunn (2015) and Fossati and Hutton (2002). However, Vose and Wiley (2008) warns that simulation methods should only be applied in situations where mathematical computations are not possible due to the fact that simulations provide approximate answers, while mathematical approaches provide exact answers.

As an approach to analysing systems as discussed in detail by Kelton and David (2008), simulation models are either static or dynamic with respect to time, as summarised in Fig 4.3.

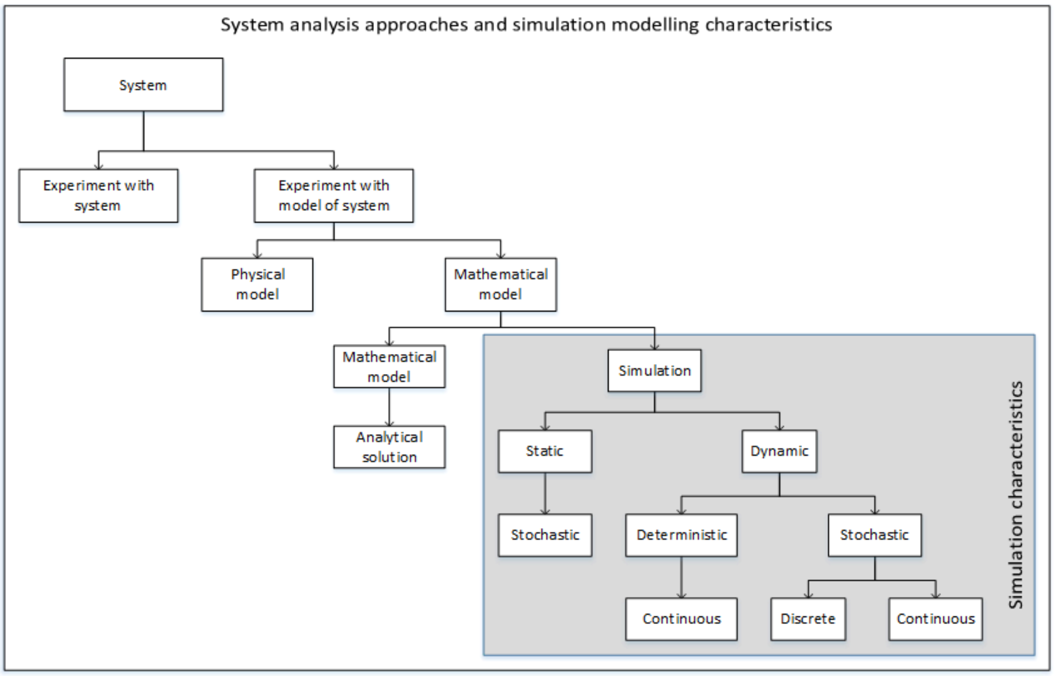

Figure 4.3: A summary of system analysis approaches and characteristics of simulation methods. Adapted from Reeb and Leavengood (2003); Kelton and David (2008)

On the one hand, static models represent a dynamic system in a static manner or a system at a specific time, i.e the model does not change with respect to time. The dynamic model on the other hand describes the system to capture its behavior with respect to time, with a different set of conditions (Reeb and Leavengood, 2003). The nature of the variables for both static and dynamic models can be described as stochastic or deterministic. Stochastic models contain at least one random or probabilistic variable that describe the system. Unlike stochastic models, deterministic models assume that model parameters have no variability, therefore the system variables are not random and outputs are an measure of the model's performance. The discrete and continuous nature of simulation models describes how each event vary with respect to each other. This characteristic distinguishes discrete simulations as having finite increments or increase at defined points with respect to time, while for continuous simulations, the variables continuously change over time (Reeb and Leavengood, 2003; Kelton and David, 2008).

Whitman *et al.* (1997) explains that the static simulation models are useful to determine different flow paths of entities throughout the system in order to identify which ones are involved in which process as well as their function. As discussed by Raychaudhuri (2008); Vose and Wiley (2008), due to the nature of uncertainty environment in petrochemical production activities, one such stochastic simulation tool is Monte Carlo simulation. According to Birta and Arbez (2013), the Monte Carlo simulation was used as early as the second World War to solve complex nuclear bomb design problems. Monte Carlo simulation allows for modelling of systems in a manner that accounts for uncertainty by integrating deterministic or stochastic techniques with probabilistic approaches to estimations, argue Shereih (2015); Raychaudhuri (2008); Law (2010).

Monte Carlo simulation is therefore an experimental tool to generate random numbers in order to solve time independent problems of a stochastic or deterministic nature. Kelton and David (2008); Reeb and Leavengood (2003) further explain that Monte Carlo simulations allow the model to use random numbers to solve stochastic problems by reconstructing the system condition with respect to events and random data points appearing every time, resulting in a statistical distribution for both input and output parameters.This provides the system analysis process with a methodical means to perform approximations for 'what-if' analysis as discussed by Raychaudhuri (2008). Kelton and David (2008) cautions that since stochastic models also generate random outputs which are themselves estimates of the characteristics of the system, care must be taken in not interpreting results as point estimates to describe the system.

4.5.5 Scenario-based models

Groves and Lempert (2007) suggests that scenario-based models contribute greatly to discussions by simplifying complex systems. Groves and Lempert

(2007) suggests that scenarios are good for communicating; potential seriousness, uncertainty, risk assessment and reference for future analyses as well as policy options (Groves and Lempert, 2007). Various scholars have made use of scenario-based models to evaluate the effects of policy options including Weidenhaupt *et al.* (1998); Wilson *et al.* (2006); Allwood *et al.* (2008); Bellù (2013); Bergh *et al.* (2013); Ederer and Reschenhofer (2014); Van Der Merwe (2015). Among these studies, scenario-based analysis by Bellù (2013) and Bergh *et al.* (2013) successfully assessed industry-wide impacts of a policy on value chains.

Scenario-based policy analysis approaches were found to be applicable to the current study as it allows industry wide analysis by evaluating policy effects on the whole value chain as is intended by developmental pricing. Another tool described by Bellù (2013) is a model of impacts which illustrates transmission mechanisms through 'cause-and-effect cascade' of causal links between value-chain variables directly influenced by a policy intervention. Important changes to quantify in a model of impacts for value chain analysis include yields, output produced per producer, total quantities produced in the primary production and downstream segments, prices of outputs due to productivity and production changes, production costs and margins to producers.

Counterfactual policy impact analysis framework

Bellù (2013), and Pesaran and Smith (2012) have reported findings based on a similar scenario-based analysis, but call the framework counterfactual analysis. The framework considers quantifiable means to rationalise the possibility of success of desired socio-economic development objectives to be achieved by proposed policy options. Bellù (2013) considers this framework to be best suited to value chain analysis arguing that counterfactual analysis is applicable for analysing broader socio-economic systems, therefore it has potential to be used as a tool by analysts to quantify possible impacts of policies in value-chain improvement. According to Bellù (2013), this framework analyses the impact of policies based on comparing two value chain system scenarios; one without the policy (base scenario) and another with the proposed policy (counterfactual scenario). The scenario without the policy is used to benchmark the impact or effect of implementing the policy intervention for the value chain analysis.

Policy analysis using this framework requires a value chain impact model to identify, describe and quantify changes likely to be induced in the value chain by policy interventions. Such indicators would have to be related to the policy objectives applicable and comparable for both the 'base scenario' and the 'counterfactual scenario' to indicate changes in the value chain as a result of the policy.

4.6 Cost classification for HCIs

In order to quantify the impact of developmental pricing on expected revenues and future attractiveness of the industry, a discussion on the most common cost components in HCIs will be outlined here. In general, costs are classified as production costs and capital costs as outlined by Tien (1998) and summarised in Table 4.3.

Table 4.3: Summary of cost classifications for mining, oil and gas related industries

Cost categories		
Cost category	Nature of cost	Cost description
Capital cost		Include expenses associated with acquisition and development of capital assets with a benefit horizon extending over several years.
	Depreciable investment	The investment is allocated to a capital asset over the useful life of the asset. Formula applied is governed by tax law.
	Expansible investment	Expenditures that are flexibly charged either against revenue or capitalised and amortized over a period for taxation purposes. An example is mine development charged at same rate as ore mined.
	Non-deductible investment	These expenditures represent capital costs that are not tax deductible.
Operating cost	Direct production cost (Variable costs)	Production process related costs such as labor, maintanance, materials and supplies directly consumed in direct proportion to level of production.
	Indirect production costs (Fixed costs)	Costs independent of level of production, sales volumes or level of output over a specific range. Examples are depreciation, utilities, insurance and rent.
	Contingencies	Expenditure reserved for use at the discretion of managers
	Distribution costs (Semi-variable costs)	Includes costs subject to managerial accounting policy involved in distributing, sometimes advertising and other expenses that vary with volume.

In addition to production costs, companies in the mining, oil and gas industries incur costs associated with new projects categorised as acquisition costs, exploration costs and development costs as discussed in detail by Vitalone (2016). In the context of accounting practices and financial reporting for companies in the mining, oil and gas exploration, a common financial measure reported is operating expenditure (OPEX). The total cost would therefore be the sum of total fixed costs and a volume function of total variable costs per unit such as total cost of sales. An example of including cost of sales and operating costs directly related to physical activities in producing specific products as operating expenditure (OPEX) is described in detail by Hecla Mining company (2011). Based on the data available for the polypropylene upstream industry, total cost of sales was the best tool to use as a relevant measure for the current study. This was necessitated by the lack of access to information related to specific production of polypropylene products as a result of the integrated and diversified nature of production activities in the value chain. Publicly available information in financial statements was found to aggregate all costs in activities involving polypropylene and other polymers from production to sales, making it difficult to separate direct and indirect production costs for the local polypropylene industry. The total cost of sales were then compared to international direct production cost benchmarks to estimate local production costs in consultation with industry experts as discussed in Section 7.1.3. Other cost-based methods based on perfect information are discussed by Al-Sahlawi (2014); Hilton and Platt (2014), especially break-even analysis.

4.7 NPV, WACC, IRR and decision modelling

Approaches considered for evaluating future returns and attractiveness of the polypropylene upstream industry based on risks and returns include weighted average cost of capital (WACC) and the internal rate of return (IRR).

The formula to calculate WACC is shown in Equation 4.1,

$$k_c = k_e \frac{E}{D+E} + k_d(\frac{D}{D+E})(1-t) \tag{4.1}$$

Where:

k_c - the Cost of capital,

k_d - the Cost of debt,

k_e - the Cost of equity capital,

E - the Equity,

D - the Debt,

t - the tax.

Guerard Jr (2005) points out that WACC is a company specific capital budgeting decision rule. It is therefore used as a company specific discount rate used to evaluate new projects and is also termed the organisation's hurdle rate.

The IRR is calculated by making r the subject of formula in Equation 4.2,

$$I = \frac{CF}{1+r} + \frac{CF_1}{(1+r)^1} + ... + \frac{CF_t}{(1+r)^t} \tag{4.2}$$

Where:

I - the Initial Investment/Capital expenditure

CF - the expected project cash-flow

The IRR is the interest rate that would result in cash outflow, to balance cash inflows over-time. when the IRR value is, it is an indication that there is a better likelihood of yielding good returns on the invested capital, or initial cash outflow Investopedia (2015).

The formula to calculate NPV for a time period (N) is shown in Equation 4.3,

$$NPV = (\sum_{t=1}^{t=N} \frac{CF_t}{(1+i)^t}) - I \tag{4.3}$$

Where:

CF - the expected cash-flows,

i - the costs of capital or WACC,

I - the Initial Investment/Capital expenditure.

The IRR and NPV are closely related in that the NPV is the difference between the initial investment amount and the gross present value discounted at a specific cost of capital while the IRR is the discount rate required to obtain an NPV of *zero* in an NPV analysis.

The NPV, IRR and WACC are some of the common tools used by companies to make decisions regarding alternative capital expenditures and investment decisions based on their expected returns in relation to the cost of capital as discussed by Guerard Jr (2005).

However, the decision rule to evaluate both IRR and WACC requires more complete information regarding company level cost of capital in order to make appraisals of future projects. This was found to be difficult to determine for different companies in the polypropylene value chain as financing sources for the different companies are different, and discount rate rules are made by finance managers for each specific company. This would therefore present challenges in making more realistic and representative estimates for the whole industry, which would introduce unrealistic uncertainty parameters into the model.

In addition, this parameter would not be useful in evaluating industrial policy affecting the manufacturing industry such as the polymer industry since capital expenditures, currently modelled, remains uncertain in the course of the project as further investments are required for maintenance, replacement, upgrading and expanding operations as noted in SASOL (2004, 2014) *Financial Statements*. A more in-depth discussion on discounted cashflow approaches and capital expenditure decision criteria can be found in Guerard Jr (2005) and Hilton and Platt (2014).

In summary, the reviewed literature highlights that the effectiveness of industrial policy aimed at value chain upgrading depends entirely on the level and extend of contextualisation of the policy to the development stage and insertion intensity of the specific industry and country in the respective GVC.

In the advent of globalisation and neo-liberal industrial policies, as was the case in South Africa in the mid-90s to mid-2000s, the GVC framework was identified as the most suitable framework to simplify the industry structure and organisation for both a quantitative and qualitative analysis to be performed given prevailing dynamics in liberal, global economies.

GVC analysis was then combined with a Monte Carlo simulation study on combined, expected future returns for the polypropylene upstream industry. The simulation study compared two scenarios for the industry, namely, before and after the policy. Simulation was useful in approximating future conditions, activities and outputs of the value chain with limited information and high uncertainty before and after the policy.

Chapter 5

Research Methodology and data collection methods

In this chapter, an overview of some of the central themes that guided literature consultation and techniques used in this study will be undertaken. The various data sources, data selection and collection tools explored will then be discussed. The rest of the chapter will be dedicated to an in-depth discussion on the data analysis techniques selected for this study, the limitations and challenges encountered, and how these were addressed. One way some of these challenges were addressed was by way of some assumptions, and these are also briefly discussed.

Bryman and Bell (2015) highlight that there are multiple competing paradigms in business related research studies due to socio-economic, geo-political and cultural influences which result in subjectivity of uni-dimensional analysis. Consequently, Bryman and Bell (2015) recommends mixing both qualitative and quantitative methods to collect and analyse data in order to confirm findings. This approach is understood to also help with understanding the multiple dimensions of business objectives, as was done for this study as shown in Fig 5.1.

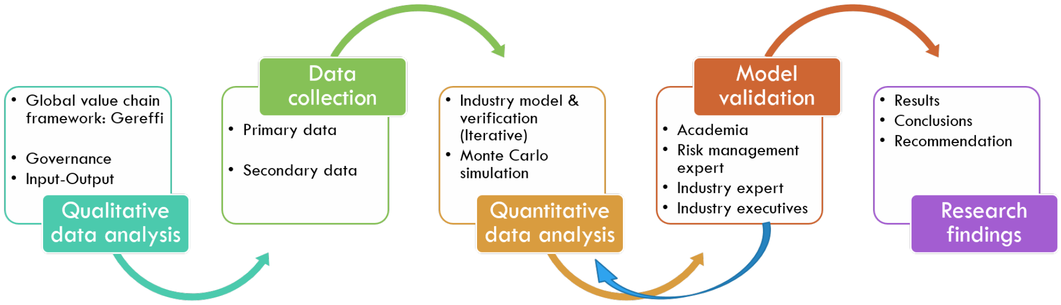

Figure 5.1: An overview of the approach used to gather and analyse data, leading to findings, conclusions and recommendations.

The study conducted a qualitative, exploratory analysis of the plastics industry by conducting interviews with various players in the industry, consulting publicly available information from databases and literature. Based on findings from the qualitative data analysis, appropriate data on the industry was then collected from relevant sources for quantitative analysis of possible effects of developmental pricing on the industry.

5.1 Central study themes

Three central themes that guided this study include industrial policy analysis, Monte Carlo simulation and global value chain analysis as highlighted in Fig 5.2.

Industrial policy analysis for this study will encompasses price regulation in the form of developmental pricing, in this case *cost-plus pricing*, which was found to be relevant for the South African context based on similar existing policies in the steel industry during the course of the study, as reported by Stillman (2011). The desired outcome of the policy proposition is reduction of input costs for downstream industries, and this study will evaluate some possible effects to upstream producers of using *cost-plus pricing* as a mechanism of input cost reduction in the polypropylene value chain.

The second study theme identified for this study is global value chain (GVC) analysis, more specifically, the input-output framework. The GVC

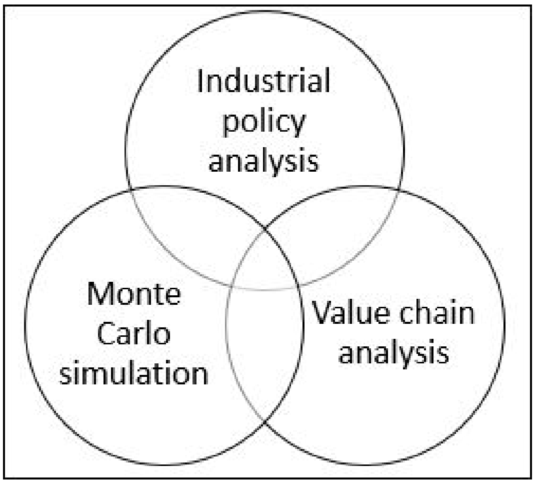

Figure 5.2: Central study themes for the current research project

analysis theme was found to be best suited for this study in providing a systematic way to evaluate the flow of materials, mass balances and revenue streams likely to be affected by the proposed developmental pricing industrial policy. This framework would also allow an analysis of exports from South Africa, and their relative contribution to revenue streams, as well as the relative impact of the policy on domestic and export revenues.

The last study theme utilised in this study was counter-factual scenario analysis for with and without policy scenarios based on a Monte Carlo simulation case study of the polypropylene upstream value chain before and after the policy. The Monte Carlo simulation enabled the study to generate multiple random production and price data points for the industry based on historical distributions for respective tiers and products. The Monte Carlo simulation model was then used to evaluate the policy with respect to possible changes to expected revenue streams by sampling data points from simulation generated values.

5.2 Data collection

Table 5.1 summarizes major sources of data consulted for this study.

Table 5.1: Sources of primary, secondary and empirical data

Primary data sources	**Secondary sources**	**Empirical data sources**
- Industry experts - Academic experts - Research experts - Subject matter experts	- Industry & Market reports - Government/Institutional publications - Trade and associations journals - Databases - Websites and publications by research agencies - Financial news and independent researcher websites	- Interviews - Questionnaires - Company reports

A majority of the data was collected from public domains, databases, published records and court transcripts of evidence presented in pending and concluded competition cases involving some of the players in the polypropylene industry. Discussions were held with industry experts, associations, academia, researchers and government stakeholders to verify and validate some of the data. Where data was missing, attempts were made to cross-reference between different official databases to re-construct the data as far as possible.

5.3 Data analysis

The study began by mapping the local polypropylene value chain by referring to industry trade data from reports compiled by companies, the government, research agencies, associations and other relevant databases, with assistance from subject matter experts. The GVC analysis was limited to analysis of imports and exports, since all upstream lead firms were found to be domestic, with a global market reach as well as some recently enlisted international shareholders. The possible effects of developmental pricing will be determined by performing a counter-factual scenario analysis on industry data points generated from Monte-Carlo simulation of the value chain.

5.3.1 GVC Analysis: Polypropylene industry

The advent of globalisation and international trade in developing countries has necessitated the development of new analytical frameworks and tools to facilitate proper planning by policy makers and practitioners to account for participation of global competitors in local value chains. An example is global value chain framework, which was used in this study to evaluate the effect of developmental pricing on competitiveness of downstream players in the polymer value chain.

The current study makes use of the governance and input-output GVC framework to perform value chain analysis, as proposed by Gereffi (2011) to evaluate the possible effects of developmental pricing on the polymer industry in using South Africa as an “upgrading” activity. Emphasis will be placed on illustrating the possible benefits of GVC analysis to evaluate industrial policy in an export-oriented developing country to inform the current policy and future studies.

GVC analysis was found to be easily adaptable to evaluate various value add trade metrics, specifically efficiency of export-oriented economies in converting domestic or imported inputs to boost growth. Furthermore, GVC analysis will be useful to understand how upgrading toward economic diversification will occur through reconfiguration of growth opportunities, especially as an adaptation mechanism to changes presented by GVCs to regionally oriented supply chains.

GVC analysis of the upstream polypropylene industry was performed for the governance and input/output dimensions. The polypropylene value chain was mapped using industry data, taking into consideration the local production capacities of polypropylene, feedstock sources, consumption, exports and other industry dynamics. Under the GVC governance domain, the various feedstock suppliers were mapped into the value chain, including ownership, products produced, relative market power or market share and capacity of operations. This was done with the view to allocate flow of products and revenues to respective producers, including indirect beneficiaries in the same value chain. A sample of the logic used to construct the value chain and its purpose for this study are highlighted in Fig E.1. Based on the value chain constructed, an evaluation of the input-output structure was undertaken for the upstream polypropylene industry using trade data and reports from companies, government departments, researchers and associations. Attempts to gather production data downstream were fruitless, and analysis of the downstream industry could not be pursued further.

5.3.2 Simulation case study

A Monte Carlo simulation model was performed using historical production data, capacity changes, exports, product prices, local demand and associated capital expenditures (CAPEX) to construct hypothetical estimates of a suitable, realistic, aggregated industry model of discounted cash flows (DCF). The model was then developed mainly from sampling risk adjusted selling prices and production volume projections from a Monte Carlo simulation experiment on the industry. Expected revenues and discounted cash flows for producers in consecutive tiers of the value chain were then obtained from the model. The Monte Carlo simulation was performed using the *Decision suite* with *@Risk* software from *Palisade Corporation.*

A counter-factual scenario analysis was then conducted on the polypropylene industry using @Risk, based on the Monte Carlo simulation data to compare the scenario with policy and without policy for the upstream polypropylene value chain. Scenario-based counterfactual analysis approaches will provide flexibility to allow qualitative and quantitative interpretation of results by comparing changes in industrial performance before and after policy interventions. The counterfactual scenario analysis on the Monte Carlo simulation data will also be performed on a *decision tree* constructed from the propylene value chain, also part of the *Palisade Corporation Decision suite.* This was done in order to evaluate polypropylene revenues in the context of other revenue streams utilising the same feedstocks for which CAPEX would have been spent in the value chain. All these approaches are being proposed to provide a holistic approach to support a techno-economic analysis on the impacts of developmental pricing on the polymer industry value chain.

5.4 Study limitations and challenges

The study was limited to upstream production activities of the propylene value chain since no response was received on requests for information, interviews, surveys and questionnaires from the downstream industry. Upon further consultation with industry advocacy groups, it was learnt that due to pending and on-going pricing practice investigations, industry players were cautious with the information they shared and participation in research studies, especially those related to pricing of polypropylene. The study consulted publicly available data such as financial reports, company websites and transcripts from court cases to construct the value chain and evaluate the industry. This was only possible for publicly listed companies or subsidiaries of publicly-listed companies. The challenge with this information was that some of the information conflicted with some reports in the public domain, and to address this challenge, the information was cross-referenced with financial statements, company reports and other government administered databases. It is also important to state here that only companies involved in direct production activities in the polypropylene value chain were considered for this study. Auxiliary service providers such as distributors and marketing companies were not investigated for this study due to difficulties associated with estimating and standardizing economic value added by activities conducted by these companies.

For the simulation case study, the major limitation was not being able to acquire production data, price information and costing data for the local industry in order to have better estimates of conversion factors, production efficiency and expected revenues. In order to overcome this challenge, company reports were scrutinised as far as possible to calculate these backwards from sales figures and capacity data. The analysis of financial statements and company reports presented some challenges in reconciling each company's financial trading years with other companies to ensure that comparisons are made for similar trading periods. To overcome this challenge, the reports were not compared in the year they were reported, but the preceding year regardless of the month they were reported. Contributions to the industry production activities by companies that are venture projects by companies that also have beneficial interest in the propylene value chain were treated as separate entities so as to ensure that any future ownership changes would not affect accuracy of the model.

5.5 Key assumptions

The main simplifying assumptions made for the industry to reduce bias to one company include aggregating the industry CAPEX, capacity utilization at local demand levels of 220 ktpa, global prices for products, global cost benchmarks, and an evaluation of earnings before depreciation and tax. The reason for not including would be depreciated at different rates over different periods. Taxable income could also not be determined with the limited information available.

For the purposes of the current study, effects of the policy on crude oil feed-stocks supply on the polypropylene upstream industry with respect to sourcing crude oil from global supply chains was not investigated. This was because crude oil feed-stocks, which are sourced from global suppliers, account for less than 10% in contributions to the polypropylene industry through chemical feed-stocks which are in essence by-products of refinery activities. For this reason, it was decided not to pursue effects of crude oil availability and price on the polypropylene industry. In addition, some constraints exist preventing extraction of chemical feed-stocks from crude oil refinery condensates. In this regard, there was no evidence suggesting that there will be a future increase in crude oil utilisation to supply chemical feed-stocks to the polypropylene value chain. Some of the major constraints were found to be availability of infrastructure such as propylene purification units and pipelines to transport propylene gas from the refinery.

Annual production estimates were made on the assumption of operations running for 365 days for each year, and annual factory down-times for maintenance and other inconveniences were accounted for by adjusting daily minimum production. In cases where data from sales and production could not be determined, it was assumed that the minimum and maximum production would be approximated at 70% and 90% of capacity respectively by benchmarking with other local and international oil and gas company reports.

Actual sales data could not be accurately established for all industry players and it was assumed that all produced products would be sold for each operational year. This could possibly lead to some over-estimates in revenues and cash-flows from unsold products in the inventory. However, this assumption was acceptable since the policy evaluation was performed to show expected revenues from the complete sale of products. The local market conditions were assumed to be consistent with constant demand markets, with small increments in demand of up to ±5% included in the model to accommodate for increased demand when prices decrease for the policy scenario, based on import quantities. The model also assumed that there would be no import penetration during the course of the policy. This was an acceptable assumption since the industry reports that demand has remained constant, even at prevailing prices to be addressed by the policy.

Chapter 6

Polypropylene GVC Analysis: South Africa

Section 6.2 will discuss findings on the global outlook on feedstock sources for the chemical sector a whole, since the polymer industry is a sub-sector of the chemical industry. This will be followed by Section 6.3 to discuss findings related to the plastics upstream industry in South Africa. Findings on the South African polypropylene upstream industry input/output and governance structures will be presented in Section 6.4 and Section 6.5 .

6.1 Introduction

The plastics industry compromises companies involved in the manufacture and or distribution of chemicals used for the production of films, fibres sheets, rods and related materials. Products from the plastics industry have widespread markets ranging from households to institutions and broader economic sectors. Plastic products have various uses in widespread economic sectors and industries at multiple levels and scales in society. Examples of uses of plastics include as packaging material, as key materials, furniture and fittings in building and construction, as consumables, appliances and spares in households and institutions such as health-care; and as components in agriculture, aerospace, automotive, telecommunications, electronics, marine, industrial equipment, lifestyle and leisure goods (Demirors, 2011; Feldman, 2008; Subramanian, 2015).

Subramanian (2015) and Eyerer *et al.* (2010) point out that plastics can generally be regarded as polymer products due to the fact that they are high molecular weight macromolecules. They are chemical compounds produced by combining a large number of much smaller, low molecular mass building blocks (monomers) in a chemical process called polymerisation. Plastics can be produced from chemically converting macromolecular natural compounds into different structures or reacting one or more monomers to obtain natural and synthetic plastics respectively (Eyerer *et al.*, 2010). Depending on the number of different monomer types used to build the polymer chain, the polymer can be classified as a homopolymer or copolymer. Homopolymers are polymer chains containing one type of monomer, while copolymers are those that contain two or more monomers (Subramanian, 2015).

Polymers used for plastics are carefully designed to optimise economic production, "processability", utility and recovery, explains Eyerer *et al.* (2010). Plastics and more generally polymers, have over the ages been designed to maximise their great advantages over metals and other materials due to the fact that they have better resistance to corrosion by atmospheric and chemical agents, much lighter in weight, and more pliable (Subramanian, 2015). This has created many opportunities for value creation in the plastics industry, ranging from sources and types of raw materials used, chemical processes to produce the plastics, chemicals to modify the plastics by enhancing strengths and improving processability, plastic product design and marketing. Polymers most commonly used as plastics include polyethylene, polypropylene, polystyrene, polycarbonates, polymethylmethacryate or polycarbonate, polyesters, PVCs, and polyamides such as nylon (Mathias, 2005).

6.2 Global plastics upstream industry

In preceding chapters, it was discussed that the plastics industry shares feed-stocks with the petrochemical and energy industries. The source of chemical feed-stocks determines overall cost of production, availability and the ultimate price chemical producers will have to offer, relative to the energy market in order to secure supply in the form of contracts to refineries. In this sense, propylene and polypropylene prices are inherently related to global demand for fuels in the energy market which would represent the opportunity cost for fuel source producers. However, the details and metrics involved in the determination of the opportunity cost of supplying feed-stocks to the chemical industry relative to the fuel industry are outside the scope of this study.

The comparative advantage in liquid fuel sources and petrochemicals in South Africa is perceived to be solely due to the fact that a majority of products are derived from coal and natural gas. Coal and natural gas are cheaper raw materials compared to crude oil in the production of petrochemicals in most countries globally as illustrated in Appendix D.1. South Africa is well endowed with coal reserves, producing around 253 million tonnes (Mt) in 2014, representing approximately 3.2% of global coal production. South Africa is also a net exporter of coal, with export reaching up to 75 Mt in 2014.

The change in global production of fuel sources for the last 30 years from 1973 to 2013 is presented here to illustrate the change in supply of fuel sources in the energy market relative to chemical feed-stocks, with emphasis on renewable fuel sources. This will then be followed by an overview of the change in fuel source consumption by chemical feed-stocks to illustrate how comparative advantages South Africa might have been enjoying in the chemical sector could soon be a thing of the past, especially in the polypropylene value chain.

Fig 6.1 illustrates the increase in production of fuel sources from 1973 to 2013, especially for renewable sources such as natural gas and bio-fuels[1].

The IEA (2015*a*) estimates that the total global production of renewable energy sources (natural gas and biomass) has generally increased by around 163% from 1 631 Mtoe in 1973 to 4 284 over the past 30 years. This increase in production of liquefied fuel sources from renewable sources can also be viewed as a response to a 51% increase in demand for liquefied energy sources in the same period from approximately 6 044 Mtoe in 1973 to above 12 458 Mtoe in 2013. However, compared to the rest of the energy sources, including nuclear, solar, wind and others estimated at 13 541 Mtoe in 2013, renewables contributed approximately 34%. This contribution by , similar to crude oil, but more than coal. There is a strong possibility that renewable energy sources could surpass crude oil and coal in the near future, as technology advances make production cheaper. In addition, tougher regulations in favour

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[1] Excludes geothermal, solar, wind and nuclear

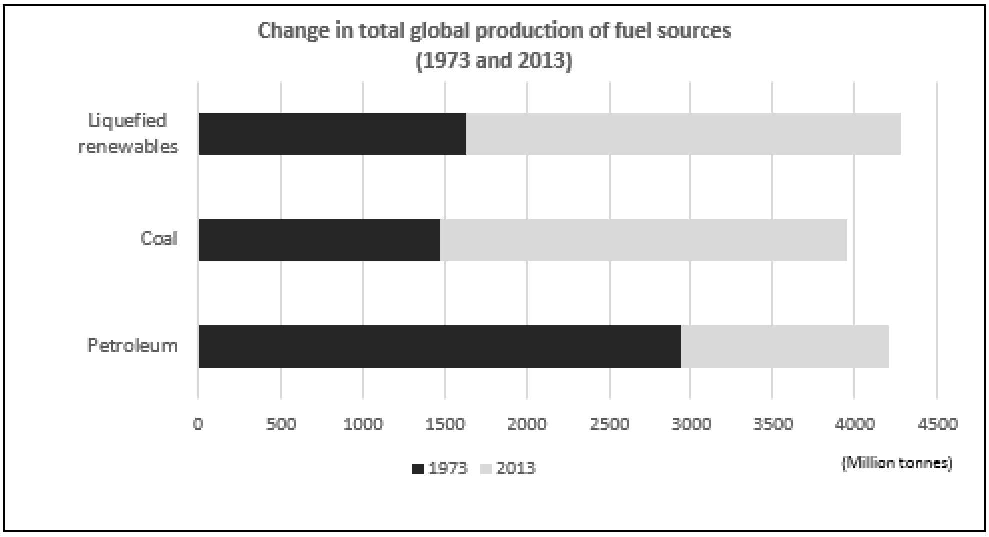


Figure 6.1: Comparison of global production of fuel sources after 30 years from 1973 to 2013. Data obtained from IEA (2015*a*).

of 'cleaner' energy sources globally might contribute to further growth of this industry.

According to data obtained from IEA (2015*a*), around 79% of the chemical feed-stocks are sourced from crude oil feed-stocks, compared to 12% and 39% for coal and renewables respectively as shown in Fig 6.2.

Production increases witnessed for renewables from 1,631 Mtoe in 1973 to 4,284 in 2013, so did consumption as chemical feed-stocks. Even though production of both coal and crude oil also increased by 168% and 43% respectively, the net increase in combined consumption of these energy sources as chemical feed-stocks was negligible. The consumption of crude oil decreased by 9%, while that for coal increased by the same margin, making the net combined consumption zero as feed-stocks to the chemical industry.

Global propylene feedstocks' changes: Stakeholder reports

Estimates by Wattanakarunwong (2015) attributed 14% global propylene supply to alternative propylene production processes that do not directly utilise crude oil feedstocks. Production of propylene from coal accounted for 1% in 2014 as shown in Appendix D.2. The highest on-purpose propylene production

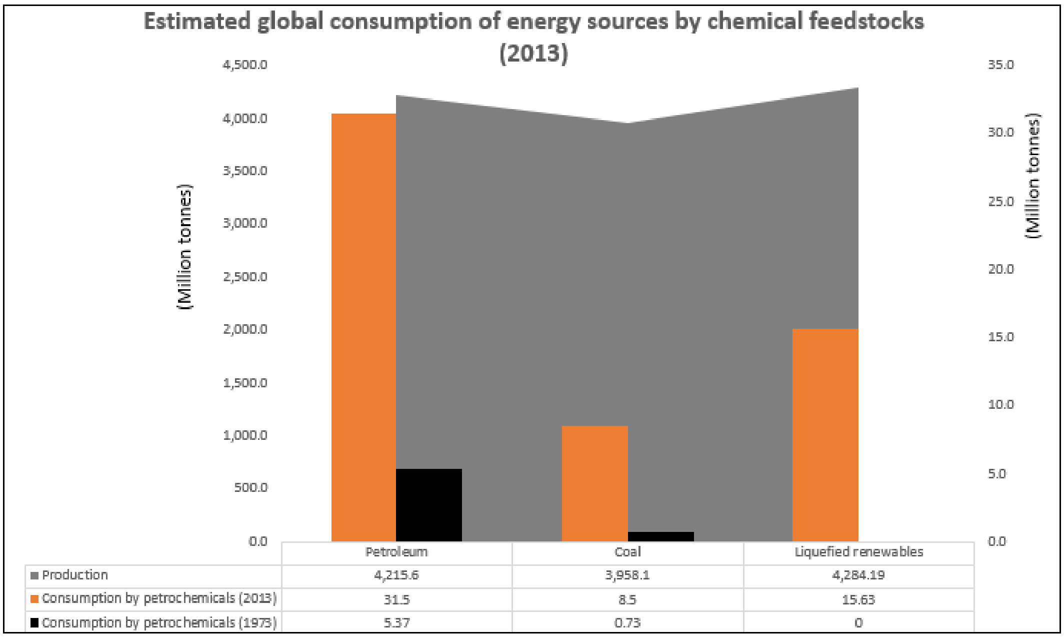


Figure 6.2: Estimated global consumption of energy sources by chemical feedstocks in 2013. Data obtained from IEA (2015*a*).

capacity additions were recorded in China between 2008 and 2015 as shown in Appendix D.3. The current trend is that capacity additions in China are leaning towards propylene production from propane dehydrogenation (PDH), with a capacity of 9 Mtoe in 2015, equivalent to 65.38% of the global PDH propylene supply. Gonzalez (2015) suggests that PDH propylene production is significantly cheaper than coal to liquids in regions where propane prices are low, and propylene prices are high.

These observations suggest that consumption of crude oil alternative sources of feed-stocks is the dominating trend in the chemical industry and might shape the future of cost leaders in the chemical industry. In the last decade, producers utilising coal feedstocks were cost leaders compared to oil refineries, however, improvements in maturing technologies such as methanol to olefins or propylene and PDH are ushering in new cycles to transform the traditional crude oil correlated prices. Coal and natural gas feedstocks remain the cost leaders in the fuel energy market, but are slowly being replaced by other alternative feedstocks in the propylene industry. However, more evidence of the cost advantages of utilising other feedstocks as chemical feedstocks besides coal, natural gas and crude oil will be needed to substantiate these observations.

Global propylene market dynamics: Opinions from interviewed industry experts

Discussions with industry experts, and confirmed by market reports by ICIS (2016), there are many factors influencing the price of both propylene and polypropylene, besides the price of feedstocks. Some of these factors include the level of global demand, source and origin of feedstocks, production cost factor advantages in the different regions, level of integration and the production technologies in use. Besides these factors, macroeconomic forces and geopolitical considerations, the key determinant of propylene and polypropylene prices in the short-to-medium term is global capacity and additional investments in capacity in any given business cycle.

A simplification of global capacity additions and vertical integration intensity is as follows. In a business cycle with fixed capacity for both propylene and polypropylene, demand for propylene will rise to exceed supply due to faster uptake of propylene by polypropylene producers. This can be due to over-utilisation and/or over-capacity in polypropylene production to meet increasing demand from downstream industries where set-up capital and production costs are much lower, and the possibility of new entrants is high. Polypropylene producers therefore strive to achieve maximum utilisation rates to meet demand and capture a larger market share, without fearing for storage and shelf-life of polypropylene compared to propylene producers. The effect of high demand will be a price increase for propylene. However, the high propylene demand will prompt producers to invest in capacity additions to absorb the extra demand in future business cycles. In this business cycle with fixed capacities, polypropylene production will be limited by propylene supply, resulting in producers being unable to meet demand, pushing polypropylene prices up. Propylene supply in future business cycles can increase to exceed demand. This can happen when new investments in capacity additions by individual companies in different regions are made regardless of how much capacity is added elsewhere since demand will not be static.

The excess propylene supply that results after capacity additions can have the effect of reducing propylene prices as producers compete to fully utilise their excess production capacity and buyers seek lower prices. This can be due to the need for economic production levels, in an effort to benefit from cost reducing effects that result from economies of scale so as to increase their profit margins and recoup their capital. The decrease in propylene prices might not significantly affect polypropylene prices since the propylene price plunge can improve margins for polypropylene producers. However, when there is a vertically integrated polypropylene producer in the value chain, this might present an opportunity for them to undercut their competitors in order to capture a greater market share. Depending on the number of vertically integrated companies in the market and the level of integration, the extent of their cost advantages and their respective production capacities, each will reduce their price proportionately. It is also possible for the integrated company to sacrifice profits for one product to capture the market in another product where they can maximise profits from either higher sales volumes or high value. As a result, the low-cost propylene producers control the floor price, while the high-cost producers act as the ceiling price for other producers, respective to the market segmentation they belong to along product differentiation.

Lower propylene prices combined with an excess supply of propylene signal polypropylene producers to start investing to increase production capacity in order to also benefit from economies of scale and absorb a larger market share. The higher profit margins enjoyed in these super-profit business cycles can also motivate polypropylene producers to plough back their profits in order to earn even better margins in future. Capacity additions by polypropylene producers can result in higher demand for propylene upstream, pushing the propylene price upwards as producers seek higher offers until demand for propylene exceeds supply. In the meantime, supply to the downstream industry will eventually exceed demand as polypropylene producers will be operating at over-capacity relative to the market demand, pushing polypropylene prices down as polypropylene buyers seek low prices until downstream utilisation and capacity increases further. This will start another cycle of investment decisions to add capacity upstream.

In summary, for any business cycle in the polypropylene upstream industry, additional global propylene and polypropylene capacities start a snow-ball effect on propylene and polypropylene prices in all regions affecting on-going and future investment decisions. Vertical integration affords chemical companies the advantage of profiting from more than one business cycle, including cross-subsidisation of operations in downward trends. This over-simplification illustrates the difficulties of balancing production, price and investment decisions in internationally trade-able products like polypropylene.

Global polypropylene production capacity

Propylene production activities in the various regions of the world create a conducive environment for expansion of polypropylene manufacturing since propylene gas is costly to transport over long distances. For this reason, the continuous capacity additions to propylene production has enabled polypropylene manufacturers to also increase capacity as shown in Fig 6.3.

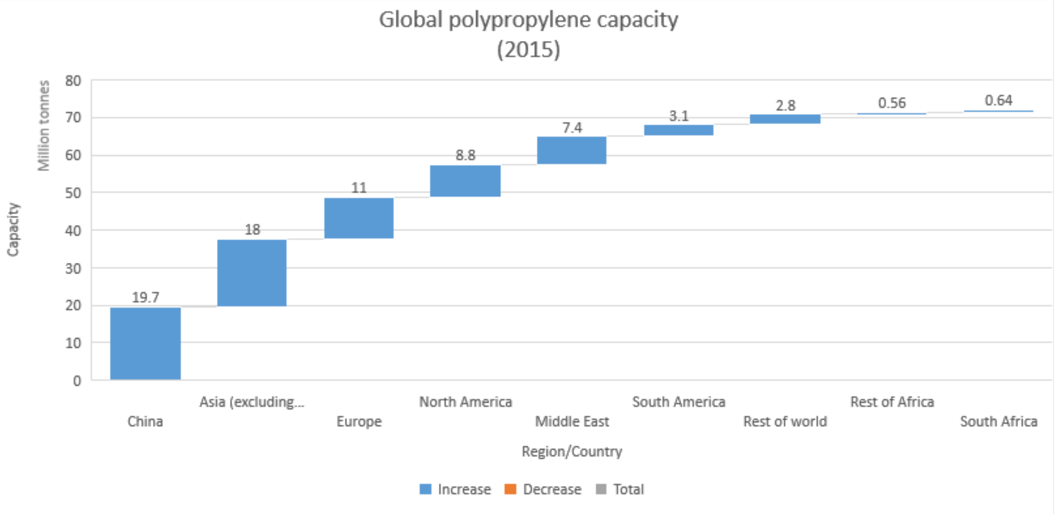


Figure 6.3: Comparison of capacities for major global polypropylene producers. Adapted from GPCA (2015)

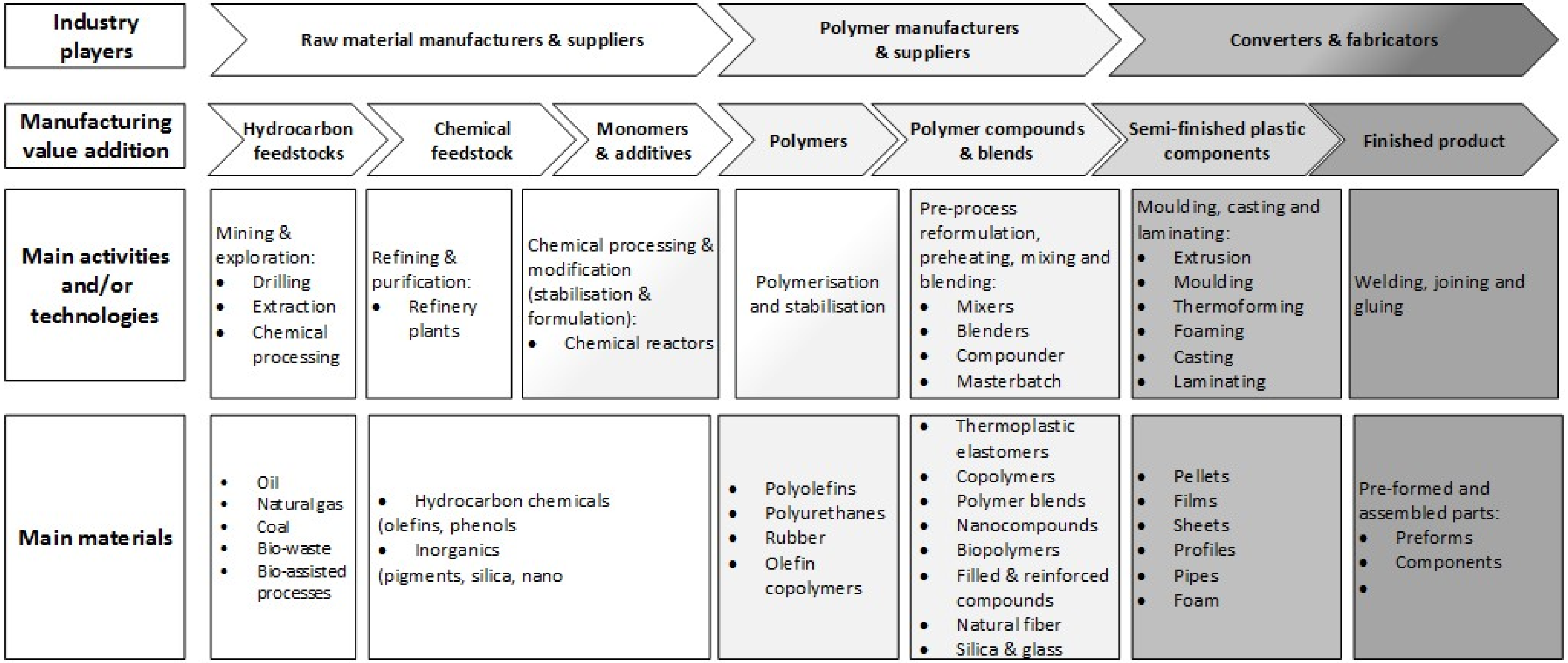
Besides being the biggest consumer of polypropylene, China has also increased its capacity to produce propylene feedstocks and polypropylene accounting for 27% of the polypropylene global supply, and 52% of the supply in Asia. These findings suggest that China might be aiming for self-sufficiency in the whole polypropylene value chain. This might be a signal for producers dependent on the China market to seek new markets, or develop more cost-efficient technologies to compete with those being developed in China. However, South Africa is the largest supplier with a 53% of the regional supply. This suggests that African markets might be the haven for South African producers if they can beat global prices and regional rivals in taking advantage of proximity to these markets.

6.3 South African plastics upstream industry

This section will briefly discuss major activities undertaken in each manufacturing tier, applicable technologies and processes will be discussed further in sections covering each tier in more detail for the South African industry.

Main activities in the plastics industry

Traditionally, business cycles in the plastic industry have been strongly linked to those of the petrochemicals industry supplying feedstocks to the polymer industry. Main activities in the plastics value chain are depicted in Fig 6.4.



Industry players	Raw material manufacturers & suppliers			Polymer manufacturers & suppliers		Converters & fabricators	
Manufacturing value addition	Hydrocarbon feedstocks	Chemical feedstock	Monomers & additives	Polymers	Polymer compounds & blends	Semi-finished plastic components	Finished product
Main activities and/or technologies	Mining & exploration: • Drilling • Extraction • Chemical processing	Refining & purification: • Refinery plants	Chemical processing & modification (stabilisation & formulation): • Chemical reactors	Polymerisation and stabilisation	Pre-process reformulation, preheating, mixing and blending: • Mixers • Blenders • Compounder • Masterbatch	Moulding, casting and laminating: • Extrusion • Moulding • Thermoforming • Foaming • Casting • Laminating	Welding, joining and gluing
Main materials	• Oil • Natural gas • Coal • Bio-waste • Bio-assisted processes	• Hydrocarbon chemicals (olefins, phenols • Inorganics (pigments, silica, nano		• Polyolefins • Polyurethanes • Rubber • Olefin copolymers	• Thermoplastic elastomers • Copolymers • Polymer blends • Nanocompounds • Biopolymers • Filled & reinforced compounds • Natural fiber • Silica & glass	• Pellets • Films • Sheets • Profiles • Pipes • Foam	Pre-formed and assembled parts: • Preforms • Components •

Figure 6.4: Summary of major exploratory, extraction and manufacturing activities contributing to the the plastics value chain. Adapted from Plastics Chamber (2012); KraussMaffei (2009)

As previously discussed in Section 3.5, chemical feedstocks for the manufacture of polymers used to produce plastics have over the years evolved from using renewable plant material to crude oil, natural gas and coal due to constraints on food and energy security. In South Africa, coal natural gas and crude oil are the only feedstocks currently being consumed by the plastics value chain as hydrocarbon sources. Condensate streams containing varying mixtures of propane and propylene from oil refineries, coal-to-liquids (CTL) and gas-to-liquid (GTL) plants are sent to on-site or nearby purification units to harvest chemical components. Various physical and chemical processes are carried out under stringent conditions to extract distillates containing chemical feedstocks of higher purity. In the various refining processes, some of the base chemicals are not extensively purified and will be used as industrial solvents and pre-cursors for the production of more complex and specialised chemicals. Base chemicals intended for use in the production of polymers are further refined to more than 99% purity, to form monomer and additive feedstocks.

Monomer feedstocks will be used as raw materials in chemical plants to produce highly complex, specialised molecules through polymerisation to form value-added products called polymers. The polymers can undergo different, controlled polymerisation reactions to produce unique compound such as homopolymers, copolymers and in some cases nanopolymers. In some cases, some polymers are first mixed or blended with other compounds to form process ready compounded polymers before distribution. Some distributors do not manufacture polymers, but they buy pre-made polymers for resale by providing warehousing facilities close to plastic manufacturers. Other distributors are referred to as compounders because they re-formulate the polymers by blending or mixing them with other products depending on requirements for further processing by plastics manufacturers before distribution. Compounders are knowledgeable about polymer formulation with other chemicals in order to achieve the desired material performance for specific end-use market applications. Some of the materials used to compound polymers include; other polymer types or natural fibres to form polymer blends and impact modifiers to enhance resistance to stress. The polymer is at this stage ready for processing by converters and is usually sold as pellets, powder or granules for ease of transport in large volumes.

Plastics manufacturers are normally referred to as converters due to the fact that they convert polymers from resins, pellets and powders to form high utility moulded components and products. Before the compounded or blended polymer is further processed, it is mixed with various additives by plastic formulators. Some additives impart special properties such as flame retardants and colourants, while others improve resistance of the polymer to shear, stress and heat during processing and end-use life-cycle. These include antioxidants, antimicrobials and stabilisers for heat and/or UV light resistance.

Plastics converters are first tier processors usually involved in processing granular or powder polymers into value-added semi-finished and finished products using processes such as pressure, heat and/or chemical modification. Other value-adding activities by converters include finishing operations such as printing and assembly for finished products. Other value adding activities performed by converters include plastic product design, expertise in processing and formulation. Plastic converters can further combine polymers with specialty chemicals called plasticisers, which are additives formulated to serve the dual purpose of optimising flow properties during processing and desired end-use material properties and characteristics.

Converters can also modify polymers further during processing by adding inorganic chemicals (fillers) like silica and glass to form filled, reinforced or nanocomposite polymers. Products from converters are destined for second tier processors (fabricators) involved in more expert design of finished plastic products using value-adding activities. Processing technologies used by fabricators usually involve melting process-ready plastic sheets, pellets or granules using injection molding, blow molding and extrusion. Fabricators produce plastic products used as components for consumer goods such as automotive parts and household items.

South Africa plastics upstream value chain: Governance

Plastic industry processors (converters and fabricators) in South Africa benefit from local polymer manufacturers that also obtain raw materials from local chemical feedstock producers, making the local plastics value chain mature, if not complete. This section will focus on organisation and governance of tiers involved in the local manufacture and supply of raw materials and polymers destined for the plastics industry. However, due to the multi-faceted nature of determinants influencing company decisions in exploiting market forces, both local and global market factors are considered, it will not be possible to comprehensively analyse all value chains in this study. Firstly, polymers produced locally will be briefly examined, followed by an analysis of local production capacity to reflect on minimum possible local market size in order to draw a few conclusions on net export potential based on maximum possible consumption downstream. In order to achieve this more concisely, one polymer value chain will be selected for an in-depth analysis.

Three main types of polymers manufactured locally that are used in the plastics industry include polyethylene (PE), polypropylene (PP) and polyvinylchloride(PVC). These polymers are manufactured by two companies, namely SASOL Polymers and Safripol using locally produced chemical feedstocks. Both SASOL and Safripol produce PE and PP, while only SASOL produces PVC as shown in Table 6.1.

Table 6.1: Summary of polymers produced by South African companies for the plastics industry

Polymer	SASOL (Base chemicals)	Safripol
Polyethylene (PE)	Low density PE (LDPE)	-
	Linear low density PE (LLDPE)	-
	-	High Density PE (HDPE)
Polypropylene (PP)	PP homopolymer	PP homopolymer
	PP impact copolymer	PP impact copolymer
	PP random copolymer	PP random copolymer
Polyvinyl chloride (PVC)	PVC	-

Compared to other polymer products, there is perfect competition between SASOL and Safripol in the PP market since both companies produce similar products. According to ICIS (2016) market reports, polypropylene homopolymers can be substitutes for HDPE used in some plastic products such as housewares and automotive parts. This suggests that PP pricing can also influence demand in the HDPE market segment.

Monomers used to manufacture these polymers are produced by purification units operated by or on behalf of the polymer producers by feedstocks producers. Currently, suppliers of monomers to the polymer industry are Sasol Synthetic Fuels (Synfuels), NATREF and SAPREF.

South Africa plastics value chain upstream: Input/Output

The cumulative traded volumes for these three polymers between 2010 and 2014 are shown in Fig 6.5 as determined from data in Appendix D.5.

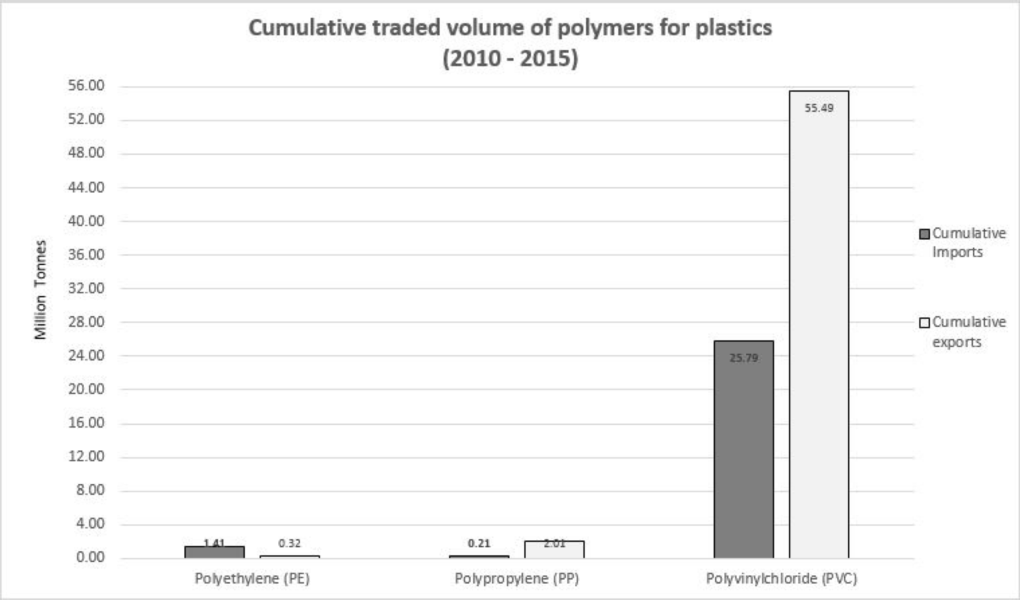


Figure 6.5: Summary of cumulative traded volumes for polyethylene, polypropylene and polyvinylchloride between 2010 and 2015. Data source: Quantec (2016)

The period between 2010 and 2015 experienced a net trade surplus in both volume (in Million Tonnes) and added value (in South African Rands) for PVC and PP as indicated in Appendix D.7 and Appendix D.6 , accounting for 3.47% and 95.98% of net exported volumes of polymers for plastics (PE, PP and PVC). Net positive exports were recorded for all PP types and a majority of PVC types. Net negative exports for PVC were recorded for non-plasticised PVC (Code: H39042100), some plasticised PVC (Code:H39042290) and PVC copolymers of vinyl-acetate (Code:H390043000). This could indicate that most PVC products are imported for the purpose of local value adding activities targeted for export markets. On the other hand, PE polymers experienced net negative export volumes in the same period amounting to a deficit of 1.09 Million tonnes (Mt), equivalent to a trade deficit of approximately R415 million. This was largely contributed by higher import volumes for PE types with specific gravity (S.G) below and above 0.94 accounting for 45.33% and 33.22% respectively, to PE imports over the period from 2010 to 2015.

Export volumes of PE types with S.G below and above 0.94 traded in this period were also high compared to other PE types, contributing 41.41% and 22.42% to PE exports within the same period. This also suggests that a majority of PE types with specific gravity below and above 0.94 are destined for value adding activities downstream to be later exported, possibly downstream. It was observed that the net export value of PE products with S.G below 0.94 (Codes: H39011000, H39011010, H39012000, H39012010 and H39012090) together recorded a trade deficit of approximately R14.048 Billion, representing 94% of the trade deficits for polyethylene products in this period. The trade volume deficit for these PE copolymers was equivalent to 1.074 Mt, representing 98.70% of the traded volume deficit for PE polymers for plastics production. Assuming that some of the imported PE polymers were destined for local downstream value adding activities, this might suggest that exported plastic products do not end up with net positive value added compared to imported goods.

However, this might be misleading since some downstream products are components of more complex finished products like car components which are not exported categorically as plastic products, let alone PE products. The only conclusion that might be drawn from these findings is simply that the export value of finished PE products is lower than the net imported value, which might arise from much larger domestic market for finished PE products. The only PE products with a net export surplus in volume and value are PE copolymers categorised as *Other ethylene methacrylate* (Code:H39019020) which traded with a net export volume surplus of 7214.93 tonnes, equivalent to R60.89 million for the period from 2010 to 2015 as shown in Appendix D.5 and Appendix D.8 respectively. Other trade balances for PE are showm in Appendix D.9, Appendix D.10 and Appendix D.11.

The net surplus in export value and volume for all PP types compared

Table 6.2: Summary of total imports of PE, PP and PVC between 2010 and 2015. Data source: Quantec (2016)

Imported polymers: 2010 - 2014			
Polymer type	Import volume (million tons)	Import value (ZAR Million)	Unit value (ZAR/Ton)
Polyethylene (PE)	1.41	19 631	13 969
Polypropylene (PP)	0.21	4 314	20 837
Polyvinyl chloride (PVC)	25.79	2 575	99.87

to other polymer types used for plastics is shown in Fig D.6, Table 6.2 and Table 6.3.

Table 6.3: Summary of total exports of PE, PP and PVC between 2010 and 2015. Data source: Quantec (2016)

Exported polymers : 2010 - 2014			
Polymer type	Export volume (Million Tons)	Export value (ZAR Million)	Unit value (ZAR/Ton)
Polyethylene (PE)	0.3169	4 665	14 722
Polypropylene (PP)	2.001	26 510	13 215
Polyvinyl chloride (PVC)	55.49	3 366	60.66

These findings suggest that the PP value chain is either more developed and mature relative to the other polymer value chains (PE and PVC) or that the local production capacity exceeds the local demand and consumption for trade-able PP products as shown in Table 6.4.

Table 6.4: Summary of cumulative net exports for PE, PP and PVC in volume (Million Tonnes) and value (ZAR Million) between 2010 and 2015. Data source: Quantec (2016)

Cumulative Net Export : 2010 - 2015		
Polymer type	Net export volume (Million Tonnes)	Net export value (ZAR Million)
Polyethylene (PE)	1.09	-14 966
Polypropylene (PP)	1.80	22 196
Polyvinyl chloride (PVC)	29.70	791

Despite high net export surplus volume, PVC products exported have inferior value compared to exported PP products each realising net added value of R26.62/Mt and R22 196/Mt respectively. In the same period, PE products recorded net deficit value amounting to R14.97 billion, suggesting that more high value PE products are imported compared to those that are exported. Appendix D.12 shows major countries of origin and destinations for PP imports and exports respectively.

Given the current benefits from PP exports, the PP value chain will be investigated further in the rest of this study to ascertain possible effects of developmental pricing on upstream activities in the polypropylene value chain.

6.4 South African polypropylene upstream industry: Input/Output analysis

The polypropylene value chain in South Africa is well developed and can be considered a mature industry since upstream supply is complete, self-sufficient and produces feedstocks for downstream industries in excess of demand. Polypropylene surplus has been estimated to be relatively constant since 2004. In that year, SASOL reported that 49% of their total production was exported as a result of excess local supply SASOL (2004). However, besides local surplus of polypropylene feedstocks upstream, the availability of propylene feedstocks to Safripol have been intermittent.

Plastics produced from polypropylene form part of the propylene value chain as shown in Fig 6.6.

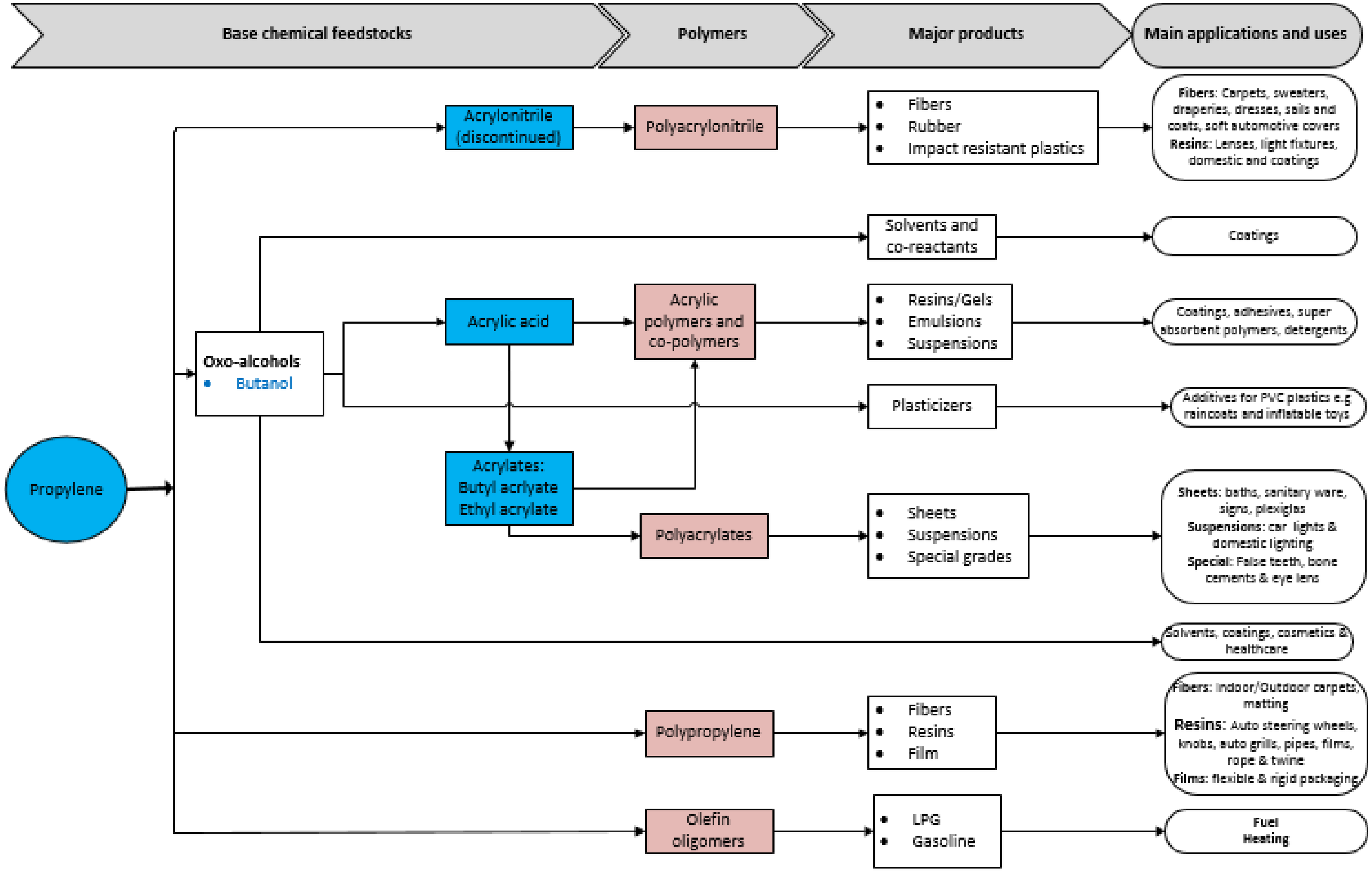


Figure 6.6: Propylene value chain and relative value overview for activities between 2010 and 2014 in South Africa.

Besides polypropylene, propylene is also used to produce other polymers. In South Africa, the only other polymers produced from propylene are acrylates, including acrylic polymers and co-polymers, using butanol as a precursor. The rest of the propylene is used to synthesise butanol and gasoline.

This section will start by examining major inputs and outputs from production activities in the polypropylene value chain. Thereafter, findings from this analysis will then be used to determine the governance structure of the upstream polypropylene industry. This will help establish how the input/output, and governance structures influence polypropylene pricing. The dynamics were evaluated with the help of industry experts to understand how they influence investment decisions on capacity additions which would lower production costs, increase local supply and boost exports for both the upstream and downstream industries.

6.4.1 Petrochemical feed-stocks

Propylene feedstocks used in the polypropylene value chain in South Africa are mainly obtained as by-products in petrochemical refineries involved in coal gasification, natural gas liquefaction and crude oil cracking. Appendix E.2 shows the conversion factors used to express all feedstocks in oil equivalent masses. The upstream value chain is summarised in Fig 6.7[2,3].

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[2] coe: crude oil equivalent

[3] Mta: Million tons per annum

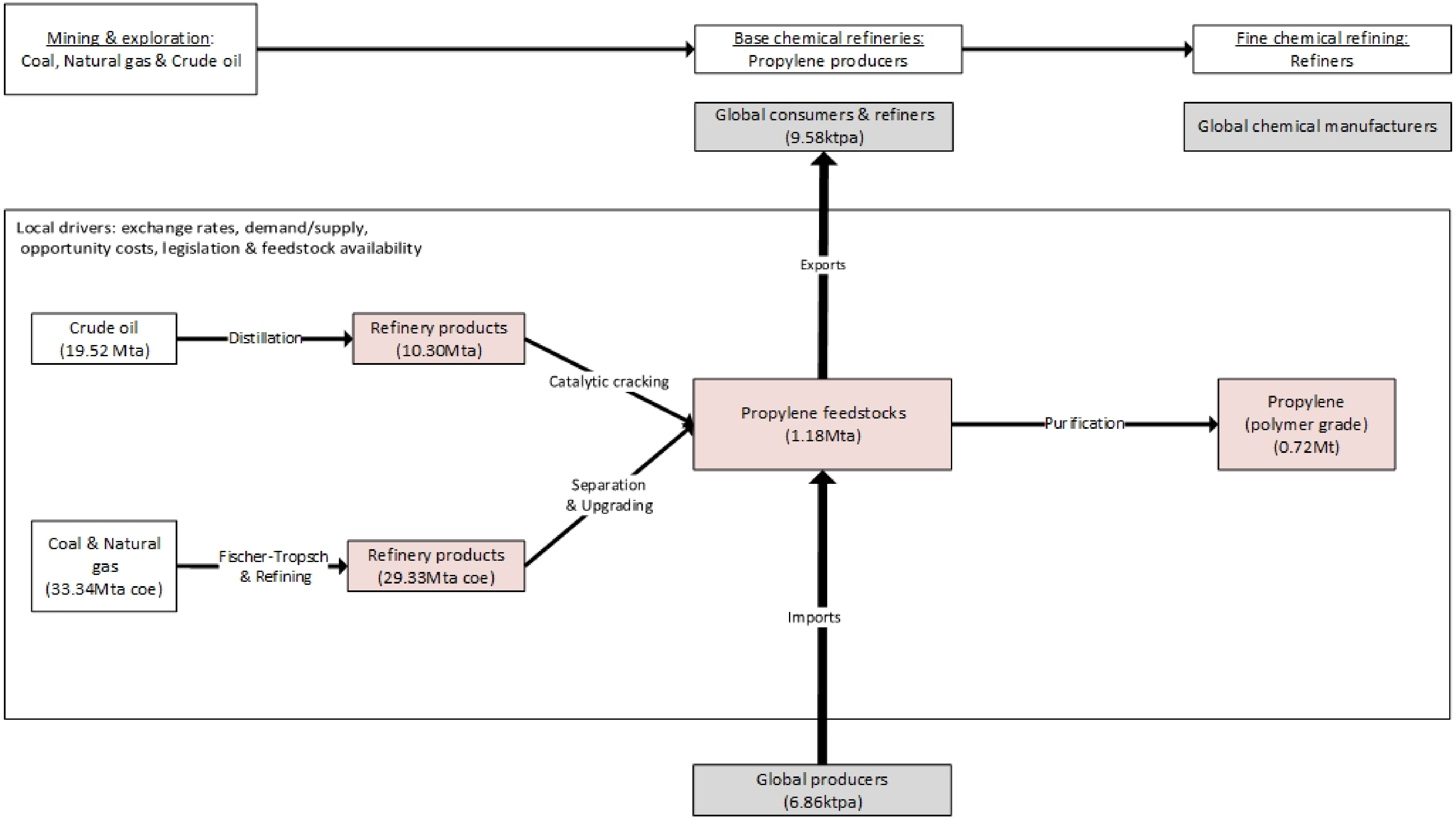


Figure 6.7: Propylene value chain chain.

The estimated amount of propylene feedstocks available for purification to polymer grade propylene from refinery products, including propylene condensates is 1.18 Mta. Based on available data, a net export of 2.72 ktpa were recorded between 2010 and 2014, representing 0.23% of local supply. The amount was insignificant compared to the consumption levels by the polypropylene industry. This internationally trade-able propylene was attributed to chemical laboratories and other chemical industries. Propylene purification units (PPUs) are estimated to produce approximately 720 ktpa of polymer grade propylene for production of polypropylene. Some of the propylene condensates are purified to chemical grade propylene for synthesis of butanol, which is also used to produce acrylates.

These findings demonstrate that the consumption of propylene feedstocks by the chemical industry, including polypropylene, is insignificant compared to consumption by the fuel industry. These results demonstrate that crude oil and coal are poor sources of propylene. Based on these findings, the propylene value chain leading to polypropylene consumes less than 2.98% volume of equivalent oil. This value could have been higher if there had been investment in infrastructure by other oil refineries to extract propylene for further purification to produce propylene.

6.4.2 Propylene feed-stocks

Propylene is a flammable gas at room temperature with various commercial uses during and after refining. Firstly, it can be used to supplement or substitute liquefied petroleum gas (LPG) for use in combustion engines and as an industrial and domestic fuel source. Major components of LPG are propane and butane, while small amounts of propylene and butylene can be present based on the quality or grade of the condensates used as feedstock. The use of propylene as the sole component in this manner is not very popular since it forms gums in valves and because the commercial value of use in this manner offers lower returns due to low prices offered by LPG customers compared to petrochemicals industries. The opportunity of use propylene in petrochemical products is therefore too high to forego by producing LPG. Logistical concerns dictate other uses of propylene due to safety and cost of transportation and storage. Propylene is transported using specialised trucks, tank cars and pipelines under pressure around 200 psi to prevent it from vaporising from the liquid state.

Refineries in close proximity to chemical companies mainly supply propylene in three grades, determined by the ratio of propane to propylene in the condensate stream. Propylene for commercial distribution is mainly available as refinery, chemical and polymer grades composed of propylene ratios ranging between 50-60%, 90 - 95% and 99% respectively as shown in Fig 6.8 (Burdick and Leffler, 2010).

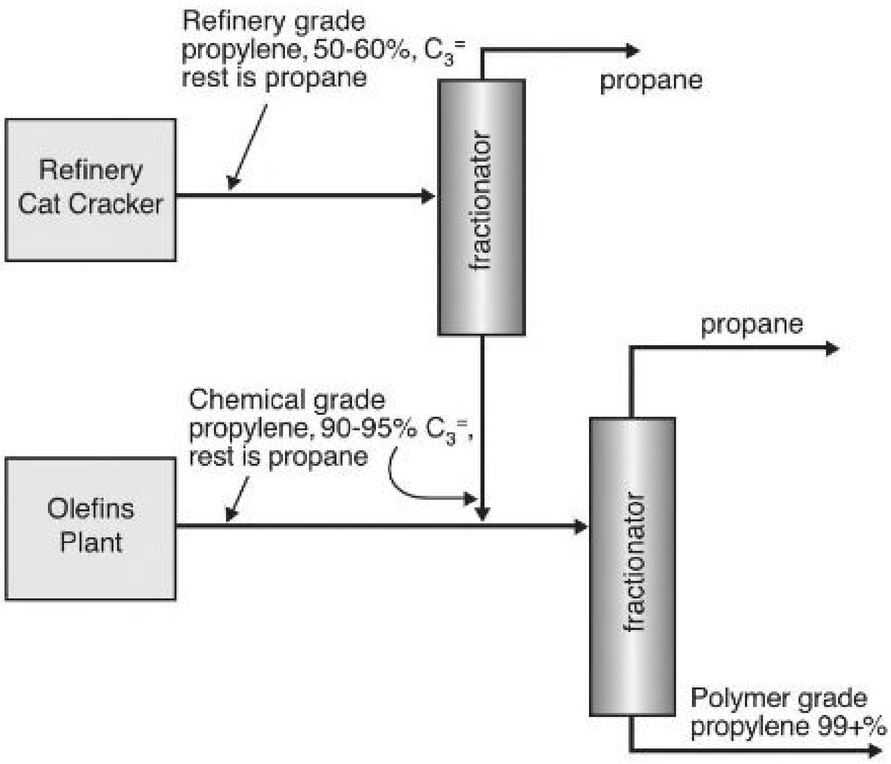


Figure 6.8: Propylene grades according to Burdick and Leffler (2010).

In South Africa, approximately 56.9% of petrochemical feedstocks are produced from coal and natural gas, via the *Fischer-Tropsch (FT)* process patented by *SASOL Investment Compony (SIC)(Pty)Ltd.* The rest is supplied from crude oil refineries, using various catalytic cracking methods using imported crude oil. Locally mined coal feedstocks accounted for an average of 88.9%

Table 6.5: Estimated propylene capacity between 2010 and 2014

Refinery	Propylene production capacity (ktpa)
Caltex refinery (Chevref or Calref)	-
Engen refinery (Enref)	29
Total/SASOL J.V[4] (NATREF)	45
PetroSA	150
BP/Shell J.V (SAPREF)	37
SASOL synfuels	900

of feedstocks used in the FT-process between 2010 and 2014, making the coal and propylene value chain a strategic asset for downstream beneficiation.

Propylene for the manufacture of polypropylene is supplied by three refineries in the Sasolburg area, which include SASOL Synfuels, NATREF and SAPREF. There are other refineries in South Africa with the capacity to produce propylene as shown in Table 6.5.

SASOL is estimated to directly supply approximately 77.6% of the local propylene, and 3.68% indirectly through its 63.66% operational share in the NATREF joint venture with Total. Propylene feedstocks acquired by SASOL is distributed among its subsidiaries for the production of various products, including polypropylene. SASOL reports that it supplied an average of approximately 12.15% to Safripol between 2010 and 2014 via a confidential agreement. The remainder was used internally to produce various products

Proximity of refineries to polypropylene producers greatly influences availability of propylene from oil refinery feedstocks in South Africa as demonstrated by Du Plessis (2010). Findings by Du Plessis (2010) indicated that refiners with capacity to produce propylene were less determined to invest in infrastructure like pipelines or trains to distribute propylene to chemical companies in need of propylene at economical cost. Fig 6.9 illustrates the close proximity of refineries supplying polypropylene in South Africa.

The other profitable uses of propylene in South African refineries is to 'upgrade' it to less volatile compounds such as isoheptane for use as a component to blend gasoline. The propylene in this case is reacted through alkylation processes with longer chain olefins, also produced during cracking and distillation processes, such as isobutane. In this case, these refiners have invested heavily in research to process propylene further for use as a feedstock in fuel produc-

Figure 6.9: A pictorial view of major oil refineries and C/GTL plants in South Africa in relation to polypropylene producers. Adapted from SAPIA (2016)

tion. The best example is a patent for the *Catalytic Conversion of Olefins to Distillates (COD)* filed by PetroSA in 2005, for the conversion of propylene into refinery distillates Minnie (2006).

These findings suggest that propylene oil refineries would need strong justification to forego profits from adding propylene into the fuel pool in favour of the highly volatile propylene feedstocks. The decision to forego profits from adding propylene feedstock to the fuel pool is evaluated against the opportunity cost in producing alternative propylene products. Fig 6.10 illustrates the relative value of the alternate fuel products taken into account by propylene producers to decide the most financially rewarding use for propylene, such as fuel, LPG and the production of butanol and its derivatives.

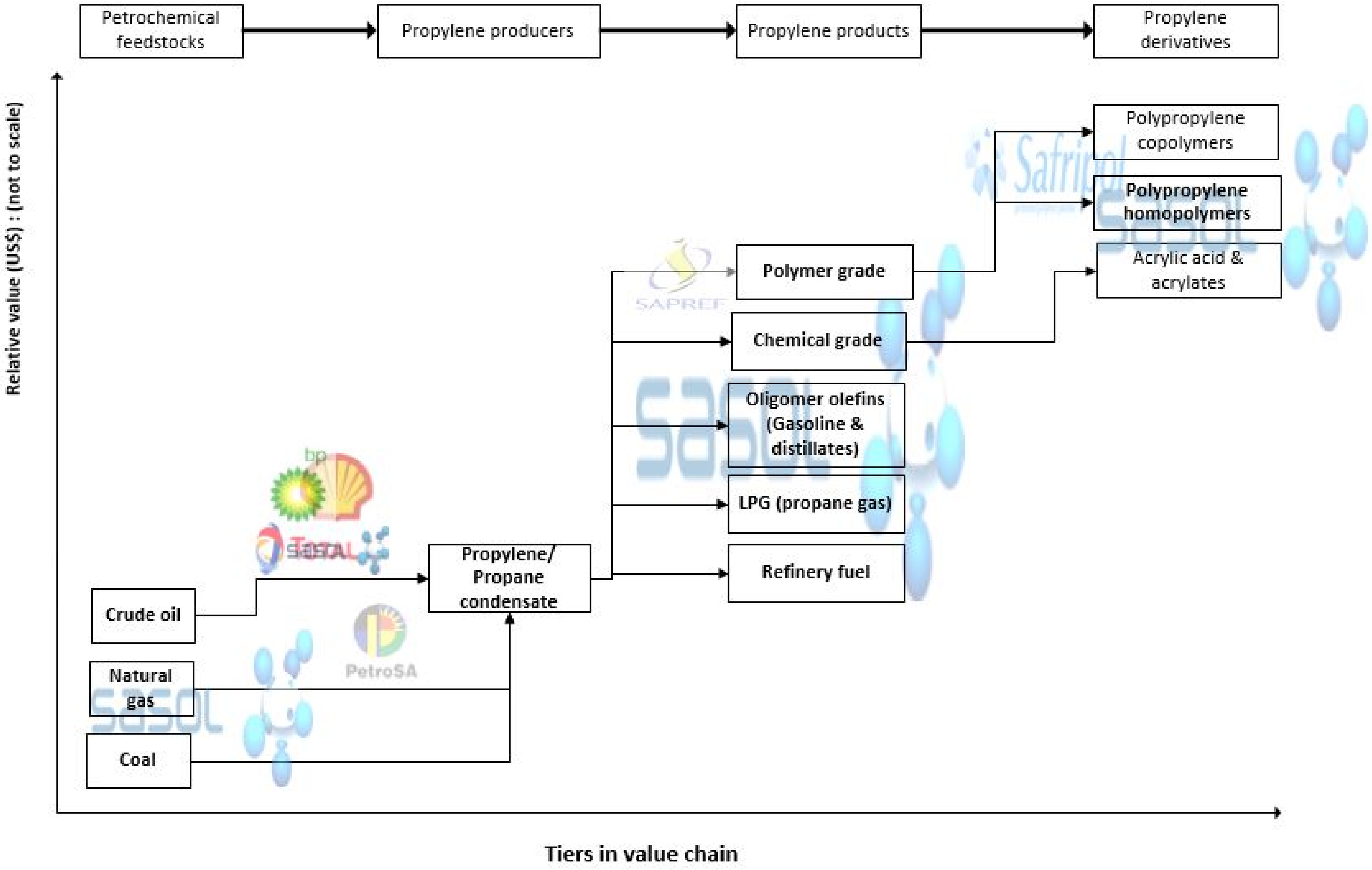


Figure 6.10: Propylene value chain and relative value overview for activities between 2010 and 2014 in South Africa.

Some of the factors taken into account to determine the fuel alternative value include crude oil prices, as well as other market forces such as demand for products and currency exchange rates.

6.5 South African polypropylene upstream industry: Governance structure

SASOL

SASOL is an integrated, power co-generation petrochemical company with full control, and in some cases, indirect access to petrochemical feedstocks in the entire value chain through its subsidiaries and joint ventures with other petrochemical refineries. Based on available data, SASOL is estimated to have full access to approximately 80.06% of propylene feedstocks in the form of condensates containing between 50-85% propylene. The propylene condensates are secured through coal gasification and refining by SASOL Secunda (previously SASOL Synfuels), using coal supplied by SASOL Mining and natural gas supplied by SASOL Gas. SASOL Mining operates approximately six coal mines in the Secunda vicinity, supplying SASOL Synfuels and its Sasolburg Operations. The coal is mainly used as a chemical feedstocks, and approximately 0.5% of the supplies is used for steam and electricity generation.

The FT-technology used to process coal and gas feedstocks is also wholly owned by SIC, also termed Coal-to-Liquids (CTL) and Gas-to-Liquids (GTL), depending on whether coal or natural gas is used as a feedstock. SASOL Synfuels is wholly owned by SASOL Investment Compony (SIC)(Pty)Ltd, operated under the Sasolburg Operations strategic business unit, previously called Sasol Polymers)) and NATREF (63.66% operational control). The various other chemical value chains being undertaken using propylene, considered as opportunity costs for operational decisions at SASOL Polymers and SASOL Solvents have been discussed in Section 6.4.2 (Fig 6.10).

NATREF

NATREF is the second refinery in Sasolburg involved in propylene feedstock production, using catalytic cracking of crude oil naptha. NATREF is a joint venture between Sasol Mining and Total South Africa each respectively having interest of 63,64% and 36,36% as well as proportionate allocation of chemical feedstocks (SASOL, 2014).

SAPREF

SAPREF is the third refinery in Sasolburg also using catalytic cracking of crude oil naptha to produce propylene. SAPREF is a 50/50 joint venture between Shell SA Refining and BP Southern Africa namely Sasol Synfuels and NATREF. Safripol has proportional access to feedstocks from SAPREF by virtue of ownership of the splitter column operated by SAPREF to produce propylene. Another consideration for access to propylene feedstocks is 25% ownership of BP‘s share of SAPREF by Thebe Investements, which also controls 20.8% of Safripol, together with Rockwood Fund I (62.1%) and Management.

Based on estimated capacities of propylene producing refineries, propylene feedstock supply in the polypropylene value chain is dominated by SASOL as shown in Fig 6.11.

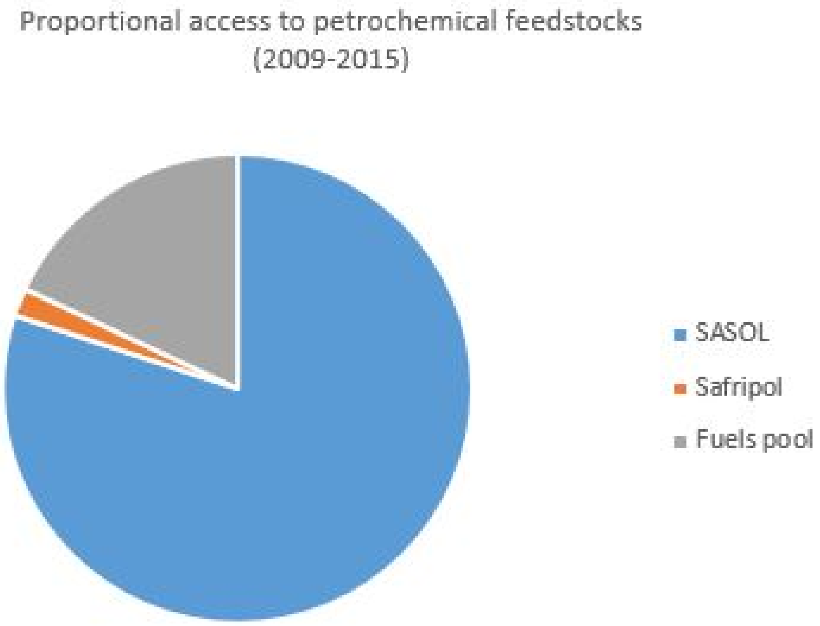


Figure 6.11: Average relative access to propylene feedstocks based on refinery capacities between 2010 and 2014.

Polypropylene feedstocks supply

Polymer grade propylene of high purity around 99% is made available from upstream processes at SAPREF and SASOL Polymers (including NATREF) are collectively made available to Safripol and SASOL, respectively. The polymer propylene grade is used to manufacture both homopolymers and copolymers of polypropylene, mainly combined with ethylene and inorganic fillers as shown in Fig 6.12.

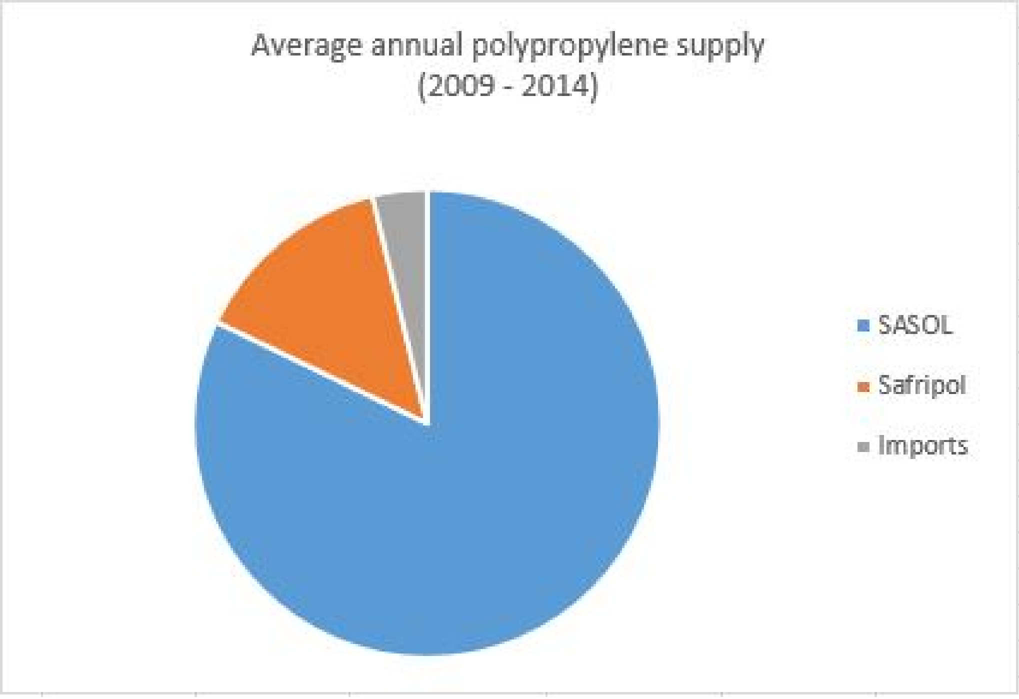


Figure 6.12: Estimated average polypropylene supplied in South Africa from 2010 to 2014.

The supply of polypropylene is also largely dominated by SASOL, with capacity to produce approximately 520 ktpa (82%) of local polyproppropylene production in South Africa. Imports between 2010 and 2014 accounted for approximately 4% of local polypropylene consumption, while exports within the same period accounted for approximately 42% of locally produced polypropylene based on capacity and data available for 2010 to 2014.

Polypropylene value chain supply: Governance

The governance structure of the polypropylene value chain is largely dominated by SASOL through its subsidiaries and to a lesser, joint ventures as discussed above and shown in Fig 6.13.

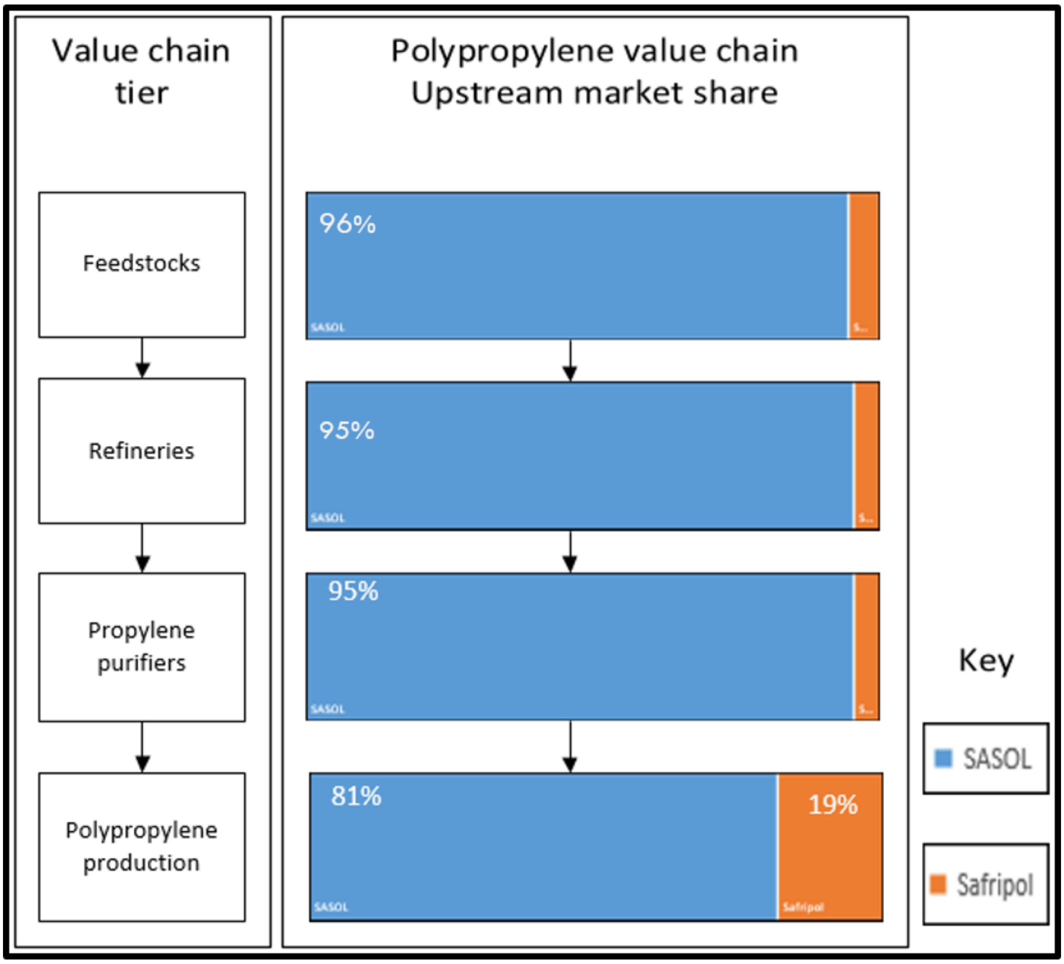


Figure 6.13: Summary of governance structure of the polypropylene upstream industry

SASOL has access to 96% of the upstream feedstocks in the polypropylene value chain, compared to Safripol, which has access to 4%. Refineries in the C/GTL and oil cracking processes containing splitters capable of producing propylene condensate in the polypropylene value chain are also predominantly controlled and operated by SASOL. Safripol only indirectly operates 5% of refineries with splitters to harvest propylene condensate through SAPREF, while SASOL directly controls 90% via SASOL Synfuels. SASOL has access to an extra 5% through its beneficial interest in NATREF, bringing SASOL's market share to 95% in the refinery tier. Propylene condensates are further purified to obtain 99% pure propylene suitable for polypropylene production. The operational and beneficial interest for propylene purification is also dominated by SASOL which enjoys 95% market share, while Safripol has access to the remainder. The current polypropylene production capacity for SASOL and Safripol brings the market share for local supply to 81% and 19% respectively.

These findings suggest that SASOL is expected to have a high degree of coordination and responsiveness to global prices with respect to upstream activities. This can increase the level of complexity with resepct to inter-firm transactions. As a result, the power asymmetry in the polypropylene upstream value chain would be in favour of SASOL, enabling it to offer better polypropylene prices compared to Safripol.

Summary of findings

Besides being the biggest consumer of polypropylene, China has also increased its capacity to produce propylene feedstocks and polypropylene accounting for 27% of the polypropylene global supply, and 52% of the supply in Asia. These findings suggest that China might be aiming for self-sufficiency in the whole polypropylene value chain. This might be a signal for producers dependent on the China market to seek new markets, or develop more cost-efficient technologies to compete with those being developed in China. Asia is the biggest market for South Africa's polypropylene products, however, its competitor in that region is China, with a 27% of global supply capacity compared to South Africa's 1%. South Africa is the largest supplier of polypropylene on the African continent, with close proximity to this market, South Africa might be able to capture this market if South African producers can offer better prices than their global rivals.

The possible effect of developmental pricing on governance structure of the value chain is that it can limit or reduce the degree of power asymmetry in the polypropylene upstream industry. However, the extent, effectiveness and success of the policy in this regard can be investigated further in order to gather more evidence. Another possible effect of developmental pricing is that it can change revenues collected in the polypropylene upstream industry. However, the extent to which revenues for SASOL and Safripol can be affected might not be the same due to differences in structures of the two companies. As an integrated company, SASOL might be able to coordinate its activities better than Safripol in response to the policy so as to offer better prices. In addition, these two companies might not realise the same costs on raw materials and production activities. The consequence of this could be that returns on current and future investments for both SASOL and Safripol might result in different capital expenditure behaviour in upstream capacity additions, cost reduction and process upgrading.

The effect of developmental pricing on future revenues and capital returns from past investments will now be investigated. This will be done to determine whether future investment decisions can be affected by developmental pricing and what the implications of that would be on the industry.

Chapter 7

Cost-plus pricing policy evaluation: Monte Carlo simulation

This chapter is dedicated to the development and application of a Monte Carlo simulation experiment using historical data on production, capacity changes, exports, product prices, local demand and associated capital expenditures (CAPEX) to estimate the Net Present Value from realistic, aggregated industry discounted cash flows (DCF). The model was developed on the basis of the value chain mapped out in Chapter 6 as described in Section 7.1 as well as respective data collected in the various tiers of the value chain. Section 7.2 will detail how NPV analysis was conducted followed by a discussion of the results. A decision tree analysis comparing revenue streams from all other activities in the polypropylene upstream value chain will be presented in Section 7.3.

7.1 NPV model building

A comparison of NPV for the scenario with and without policy was then conducted to evaluate the impact of changes in revenues on cash flows and subsequent NPV. Results from the DCF model were then used to evaluate the impact of the policy on net revenues by analysing all revenue streams in the propylene value chain using a decision tree model. The decision tree model was also constructed on the basis of the value chain analysis in Chapter 6 in order to evaluate developmental pricing in the context of other revenue streams in the propylene value chain besides polypropylene. This was done to provide a better basis for policy evaluation on the basis of how future optimal strategies might change for the industry with respect to opportunity costs, sustainability and profitability of operations in the propylene value. A counter-factual scenario approach was conducted on the polypropylene industry for both the NPV analysis and decision tree to quantitatively compare the scenario with policy and without policy for the upstream polypropylene value chain.

7.1.1 Estimation of polypropylene industry activities

The simulation model to generate realistic hypothetical estimates for net present value (NPV) was constructed from a simplified, industry aggregated model of discounted cash flows (DCF). The model was developed mainly from sampling risk adjusted selling prices and production volume projections using Monte Carlo simulation, to obtain revenues for producers in consecutive tiers of the value chain. Publicly available historical data for respective industry inputs and products in the polypropylene value chain were used to estimate realistic random values for the ten year period from 2015 to 2024. These projected polypropylene industry production activities and returns were performed using *@Risk* software from *Palisade Corporation* to perform Monte Carlo simulation. Industry experts and players in the polypropylene value were consulted to validate estimations and assumptions in the iterative stages and finalisation stages of the model. The general approach used to develop the simulation model is illustrated in Fig 7.1.

An adaptation of the risk management approach was employed to evaluate policy risks, excluding the risk management tasks since they were not applicable in this study. The final model was constructed based on a hypothetical polypropylene producer with production activities of 430 kilotons per annum (ktpa) and 300 ktpa for propylene and polypropylene respectively. These production volumes are equivalent to capacity additions to the polypropylene upstream value chain from 2004 to 2014 with capital expenditure (CAPEX) of approximately US$ 1,125 billion over the same period.

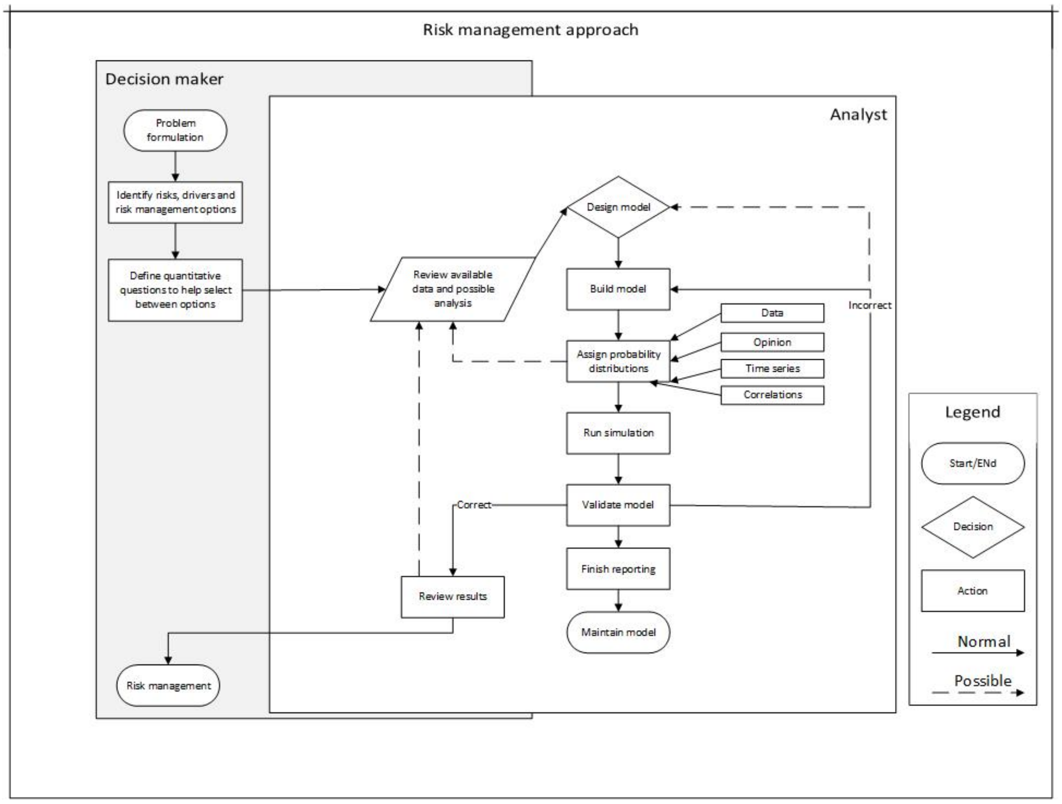


Figure 7.1: Monte Carlo simulation approach for NPV model. Adapted from: Vose and Wiley (2008); Joubert (2016)

7.1.2 Risks and drivers identification

The identification of risks and drivers for quantitative developmental pricing policy impact modelling was performed with respect to carefully selected operational parameters for the polypropylene value chain. The main risks identified for developmental pricing policy impact modelling were mainly production costs (fixed and variable) and revenue. It was noted that most of these risks are cost-related, which was consistent with the developmental pricing policy under evaluation.

In this study, major cost drivers for the value chain were isolated and aggregrated for the upstream industry, without ignoring cost dependencies on individual business economics. For the sake of simplifying the model, a hypothetical polypropylene producer was defined for the industry with characteristics of both producers in South Africa with a production scale equal to capacity additions during the 2004 to 2014 period. In order to investigate possible policy impacts, quantifiable drivers for revenue and production costs considered for this study as outlined by Rugman and Verbeke (2002) included;

1. capital expenditures and product development costs,
2. economies of scale and scope: capacity, efficiency and product mix,
3. feedstock availability: raw material costs, sourcing and logistics efficiencies
4. production costs (total cost of sales),
5. product selling price and,
6. sales volumes.

However, due to limited availability of data, sales volumes and selling prices could not be accurately modeled in this study. Instead, it was assumed that 100% of products in the value chain would be sold at global market prices for the base model. This assumption could have resulted in over-estimation of revenues for domestic sales, since no additional tariff charges and transport costs are encountered. It was decided that this assumption would be maintained in the model, as it would assist in standardising the market value of products in the base model.

7.1.3 Quantification of developmental pricing policy impact

The two questions to be addressed at this stage were:

1. What cost components could *cost-plus* 'developmental pricing formula' consider?
2. How can the impact of developmental pricing policy on the polypropylene value chain be quantified within the South African context?

First, to address the question; "What cost components will the developmental pricing formula consider?". Discussions and interviews were conducted with industry analysts, experts and some managers in the value chain to establish the best way to estimate costs, since obtaining actual costs proved to be very difficult. It was established that local production cost estimates for both propylene and polypropylene would result in gross under-estimates.

The first reason for this is that the largest producer (SASOL) is an integrated chemical company, transfer pricing formulas applied in cross-selling feed-stocks between subsidiaries and business units can result in reduction in costs by more than 50%. This is because propylene price and purification costs comprise a large portion of manufacturing costs in polypropylene production. Efforts to confirm these suggestions from SASOL were fruitless, possibly due to the sensitivity of propylene and polypropylene pricing after anti-trust litigation in that regard.

However, discussions with some of the economists involved in the anti-trust case indicated that a model based on costs reported by SASOL can result in the model making use of unrealistically low production costs for both propylene and polypropylene. Secondly, financial reports from SASOL do not report on individual product total cost of sales. Costs reported by SASOL indicated the basket costs of bundled products in the polymer business unit, and from 2014, this basket also includes base chemicals. In this case, propylene total cost of sales are bundled with those for ethylene, vinyl chloride, butanol and other base chemicals. As a result, cost estimates using SASOL's cost estimates would prejudice costs by minority non-integrated propylene producers (SAPREF and NATREF). Furthermore, SAPREF and NATREF make use of crude oil feedstocks, which require relatively more expensive production technologies different from SASOL.

Various market reports and industry experts were consulted in order to estimate more realistic global cost estimates for polymer grade propylene. The best cost estimates were found to be those reported by Wattanakarunwong (2015) as international benchmarks from North East Asia and the United States (US). The costs reported were between $US490 and US$1150/ton for polymer grade propylene, depending on the source of feedstocks, propylene quantity in the feedstock and production capacity. Estimations for propylene and polypropylene feedstocks can be regarded as representative of global averages for all different kinds of feedstocks and production technologies, including C/GTL and oil. Therefore, these estimates were treated as 'best guess' hypothetical values, as opposed to exact replicas of realised production costs by polypropylene upstream value chain producers in South Africa. The estimations were acceptable as representative of global production costs on which current and future investors can base their decisions on regarding choosing South Africa as a production base for polypropylene.

The second question to be addressed was "*How can the impact of developmental pricing policy on the polypropylene value chain be quantified within the South African context?*"

The benefit in answering this question is in the contribution it will make to providing systematic tools to analyse industrial policy such as developmental pricing policy on long-term investment returns for manufacturing industries like the polymer industry, and the polypropylene value chain in particular. The available industry data highlighted in Section 7.1.2 prompted combining discounted cashflow approaches with decision modelling. This approach was motivated by the need to highlight current long-term upstream optimal strategies in the polypropylene industry that might be disrupted by developmental pricing policy. The disruption of current optimal long term strategies could inherently affect attractiveness and profitability with subsequent unintended consequences upstream as a result of unforeseeable responsive strategies by industry players. However, the scope of the current study does not include outlining unintended consequences, but is limited to developing techniques to enable analysis of possible impacts of different developmental pricing policy options in a quantifiable manner. The current study does not attempt to address all sources of uncertainty in the polypropylene value chain. It is hoped that once such techniques are developed, industrial policy analysts would be able to appraise and identify the most beneficial policy alternatives based on quantitative approaches.

7.1.4 NPV and IRR calculations

The formula to calculate NPV for a time period (N) is shown in Equation 4.3 (Section 4.7).

$$NPV = (\sum_{t=1}^{t=N} \frac{CF_t}{(1+i)^t}) - I \ (4.3)$$

The NPV was chosen to investigate the order of magnitude to which developmental pricing might affect relative returns from capital investment decisions in the polypropylene upstream value chain. The NPV analysis approach was identified as the most realistic tool for evaluating future upstream attractiveness and profitability in the polypropylene industry since it is easier to adjust for risk considerations. The use of NPV analysis was made possible by treating the entire upstream polypropylene industry as an integrated company, cross-selling products between tiers for value adding activities at global market price, as is the case for SASOL, the dominant polypropylene producer. It should however be noted that this assumption might over-estimate revenues upstream, since it is possible that integrated firms could practise transfer pricing at below global market prices. This assumption was however an acceptable one since it estimates the opportunity cost of divestment in downstream activities by integrated upstream companies and attractiveness of the industry for potential entrants upstream.

The IRR was calculated by making r the subject of formula in Equation 4.2 (Section 4.7),

$$I = \frac{CF}{1+r} + \frac{CF_1}{(1+r)^1} + ... + \frac{CF_t}{(1+r)^t} \ (4.2)$$

in order to determine the possibility of profitability from future investments in the polypropylene value chain. The IRR was evaluated for the base and policy scenario as a profitability indicator for future projects in the polypropylene value chain, should developmental pricing policy become a reality.

7.1.5 NPV model logic

The logic followed for the NPV model construction is shown in Fig 7.2

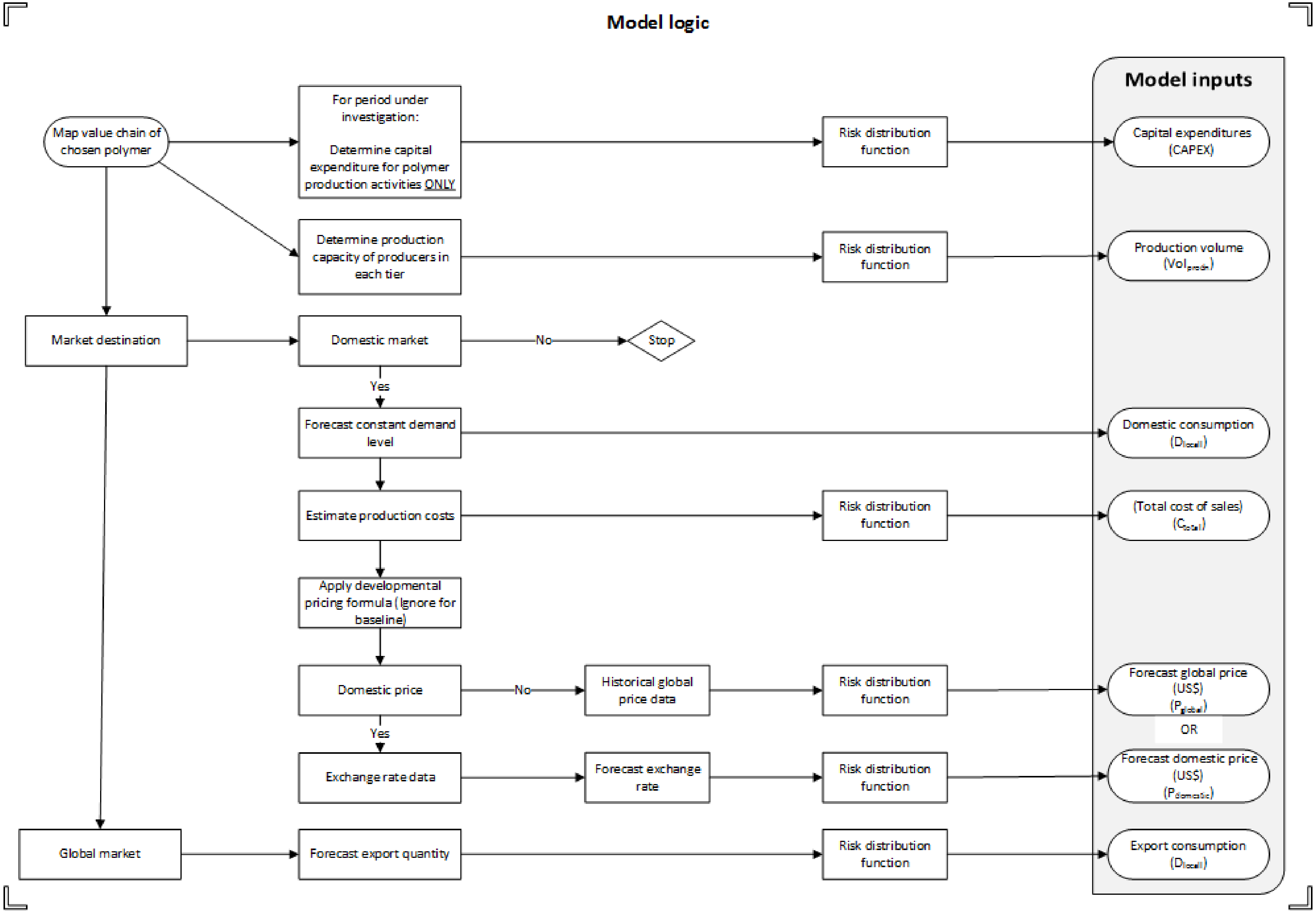


Figure 7.2: Model logic used to construct the NPV model. Adapted from Joubert (2016); Vose and Wiley (2008); Middleton (2003)

The risk distribution functions for production and price inputs in the NPV model were formulated from historical data using the distribution fitting utility in the *Palisade @Risk Decision Tools* package. Using these risk distribution functions, a set of risk adjusted random data points were generated from 5000 iterations for production volume and price in Microsoft Excel using the @Risk add-on. These risk adjusted outputs for production volumes and price were used to calculate projections for revenues from specific products as expressed in Equation 7.1.

$$Revenue(R) = \text{Production volume}(Vol_{prodn}) \text{ x Price (P)} \tag{7.1}$$

The Cashflow (CF_n) for subsequent n years were calculated as shown in Equation 7.2.

$$CF_n = Revenue(R) - (CAPEX + \text{Total cost of sales}(C_{total})) \tag{7.2}$$

The model was built on projections over the next 10 years. This period was chosen because price projections are not expected to continue following the same trend based on current assumptions for periods exceeding ten years since production capacity changes and other global demand forces might have changed beyond that period. In addition, the industrial policy environment in South Africa has historically not lasted longer than 10 years. Since the current study was investigating possible effects of developmental pricing, an evaluation of the policy over a 10 year period was found to be a more realistic time-line to reflect possible effects limited to the period of tenure for the policy.

It was not possible to calculate the industry aggregated WACC due to unavailability of sufficient data on the debt and equity capital cost structures for Safripol. The NPV was then calculated using a discount factor of 12.5%, which was above the 10 year bond yield and prevailing prime lending rates below 10.5% published by the Reserve Bank of South Africa in 2016. This rate can be regarded as the opportunity cost foregone by investors in the polypropylene industry. This discount factor was chosen as a more realistic consideration for financing decisions in the polypropylene industry since it was comparable to capital market rates for bonds maturing in 2026 as gazetted on 30 September 2016 by Reserve Bank of South Africa and discount rates reported by SASOL (2015).

7.1.6 Decision analysis: Value at Risk (VaR)

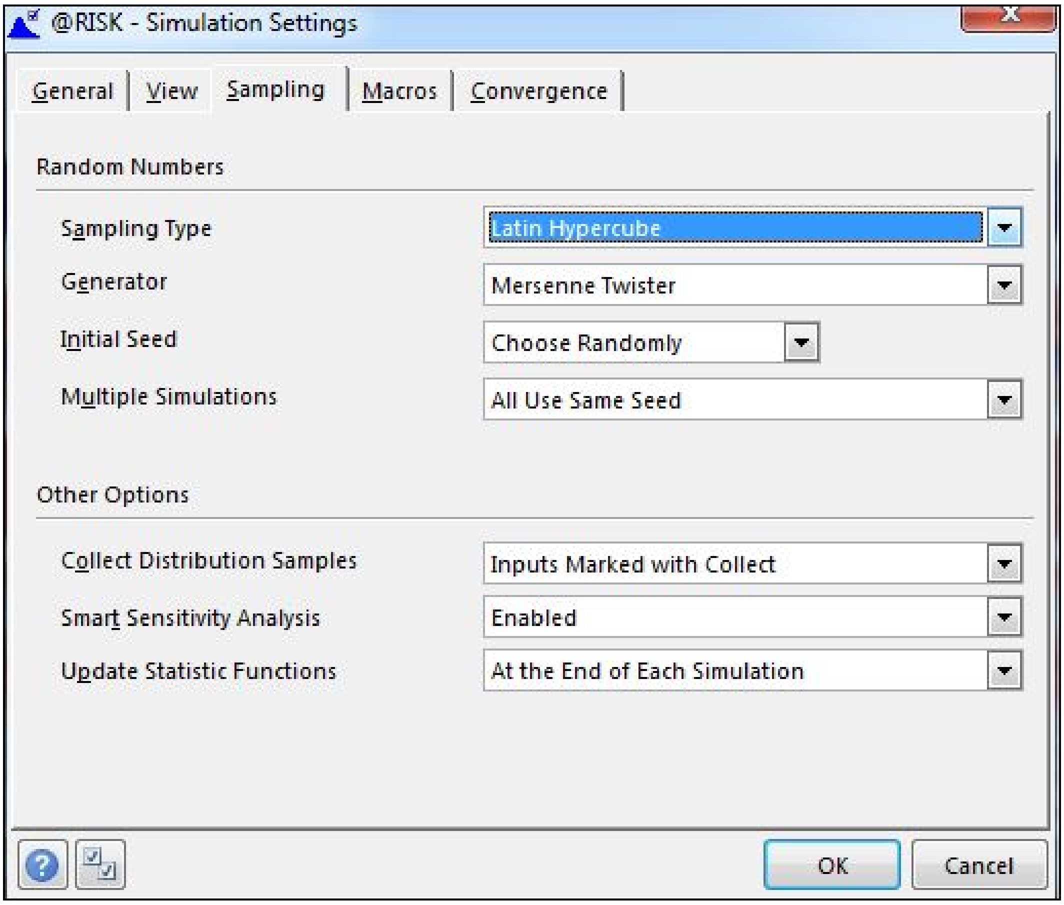
In order to illustrate the different outcomes for the scenarios with and without developmental pricing policy, a decision tree model was constructed using the approach described by Middleton (2003); Vose and Wiley (2008) as well as that employed by Shereih (2015). The decision tree approach was used to illustrate the various revenue streams in the polypropylene value chain in relation to one another. The decision trees would also be used to show how revenue streams would change with developmental pricing policy for individual products in each tier of the polypropylene value chain.

7.2 NPV Simulation and Analysis

The policy risks were evaluated using an NPV model using *@Risk* software so as to take into account uncertainties in production activities and product price volatility for future earnings in the value chain which would influence business decisions impacting the industry, especially capital investment.

Inputs and correlations for the NPV model are demonstrated in Fig F.1 and Fig F.2 respectively, highlighting probability distributions with associated correlations for uncertainties in estimating future values for these inputs. Fig F.3, Fig F.4 and Fig F.5 highlight how outputs for the model were determined.

A single simulation run of the NPV model was performed with 5000 iterations using sampling settings shown in Fig 7.3



Random Numbers

Sampling Type: Latin Hypercube
Generator: Mersenne Twister
Initial Seed: Choose Randomly
Multiple Simulations: All Use Same Seed

Other Options

Collect Distribution Samples: Inputs Marked with Collect
Smart Sensitivity Analysis: Enabled
Update Statistic Functions: At the End of Each Simulation

Figure 7.3: Monte Carlo simulation sampling settings

7.2.1 Base scenario NPV analysis

NPV uncertainty distribution results for the base scenario without developmental pricing policy are shown in Fig 7.4.

The *probability of obtaining a positive NPV* ($P_{NPV \geq 0}$) was determined for polypropylene value chain. Free cashflow from production and sales of polymer grade propylene and polypropylene were used to make this determination. The $P_{NPV \geq 0}$ was found to be 6.3%, with an expected value of -US$1,1684 billion for the simulation study. This suggests that the expected revenues collected from the polypropylene value chain at global benchmarks for costs and prices are likely to result in loss of current value.

However, these findings are limited to capacity additions of 430 ktpa and 300 ktpa of propylene and polypropylene, respectively, and both products being sold at international market prices at global production cost benchmarks.

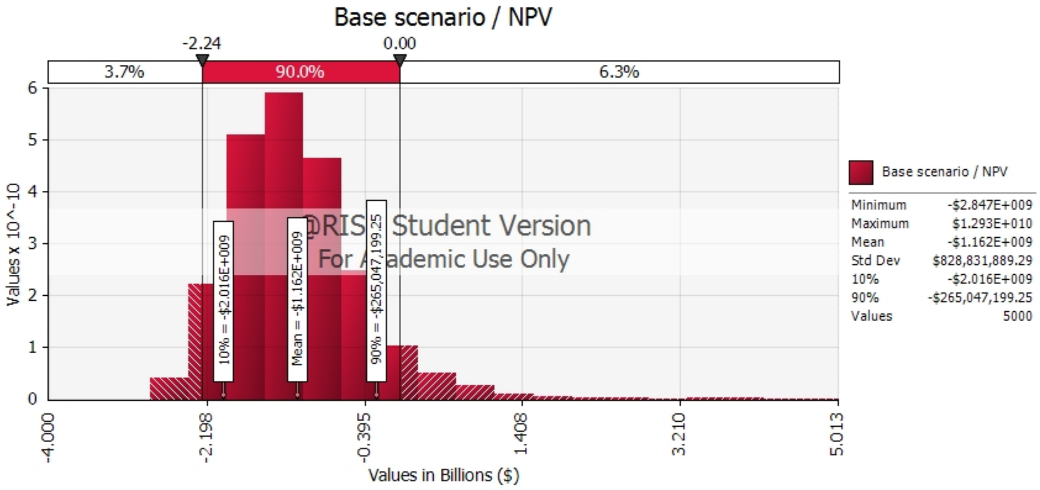


Figure 7.4: NPV results for the base scenario

This estimation also excludes export tariff charges for exported products, as well as applicable domestic taxes, since these are volume-based and are applicable on a company-to-company, product-to-product basis. With this in mind, the NPV will only be treated as a profitability indicator for comparison purposes with the policy scenario. Based on projections by this model, investments in the polypropylene value chain in combined propylene and polypropylene capacities under investigation might not be profitable within the next 10 years. As a result of the negative NPV values, it was not possible to calculate the IRR value.

Fig F.6 to Fig F.15 illustrate prices and production volumes sampled by the model for polymer grade propylene and polypropylene for the 10 year period from 2015 to 2024, while Fig F.16 shows the *P90* values for inputs and outputs for the model.

Sensitivity analysis of inputs relevant to the polypropylene value chain and outputs used as inputs in subsequent steps was performed using the *RiskCollect()* and *RiskMakeOutput()* functions respectively in *@Risk* software for years 1 and 10. The first analysis was performed using a tornado graph to evaluate the impact of production and price uncertainties of polymer grade propylene and polypropylene on the NPV as shown in Fig 7.5.

Sensitivity analysis results from this model suggest that the NPV is mostly influenced by CAPEX, followed by production uncertainty for polypropylene

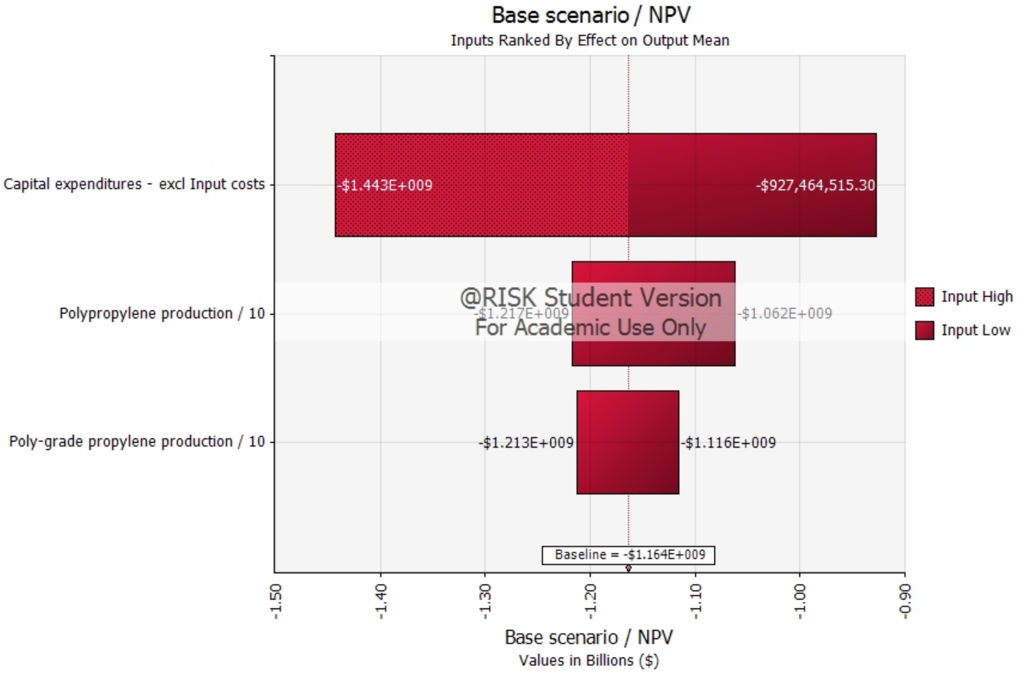


Figure 7.5: Tornado graph for sensitivity analysis of NPV to production and price uncertainty for the base scenario

and polymer grade propylene respectively. Price and production trends are shown in Fig F.6 to Fig F.15, but will not be discussed in detail since the model suggests that they have less influence on NPV.

These results suggest that profitability in the polypropylene industry might be influenced by managing and utilising production capacity more efficiently. As suggested by industry experts and as indicated by the positive IRR, further investment in capacity additions can help increase production volumes which can help reduce realized costs. Economies of scale achieved through capacity additions can absorb investment costs by increasing sales volumes, provided demand expands sufficiently enough to avoid overcapacity, which can have the opposite effect of diminishing returns.

7.2.2 Policy scenario NPV analysis

The current model includes simple market forces of price and production uncertainty, the study will now investigate how price regulation will affect future investment returns based on production predictions from this model. The NPV uncertainty distribution results for a developmental pricing policy scenario of *(cost plus 15%)* are shown in Fig 7.6.

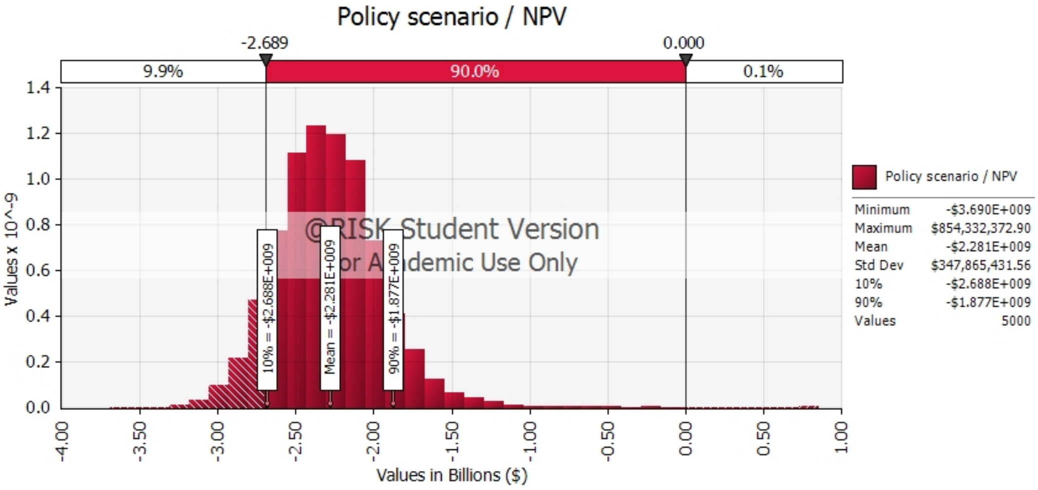


Figure 7.6: NPV results for the policy scenario

Based on the results from this model, the $P_{NPV \geq 0}$ for the developmental pricing policy scenario was found to be 0.1%, with an expected value of -US$2.283 billion. Fig 7.7 illustrates sensitivity analysis of inputs relevant to the polypropylene value chain using a tornado graph for the policy scenario.

The influence of CAPEX and production uncertainty in propylene and polypropylene activities on the NPV for this model is similar for the base and policy scenario. However, in addition to these, domestic consumption also has an influence on NPV, but to a lesser extent than the first three. This indicates that if developmental pricing is accompanied by high local demand, returns on invested capital might be negatively impacted.

Trends in price changes for the policy scenario are shown in Fig F.17 and Fig F.18. The production volumes sampled in the policy scenario were the same as those for the base scenario. Fig F.19 illustrates a the decline in *P90* values for the policy scenario.

Attractiveness of the polypropylene upstream value chain under developmental pricing is expected to be very low. This can have the effect of discouraging further investments in capacity expansion to grow the market and increase exports upstream. The effect on the downstream industry was not

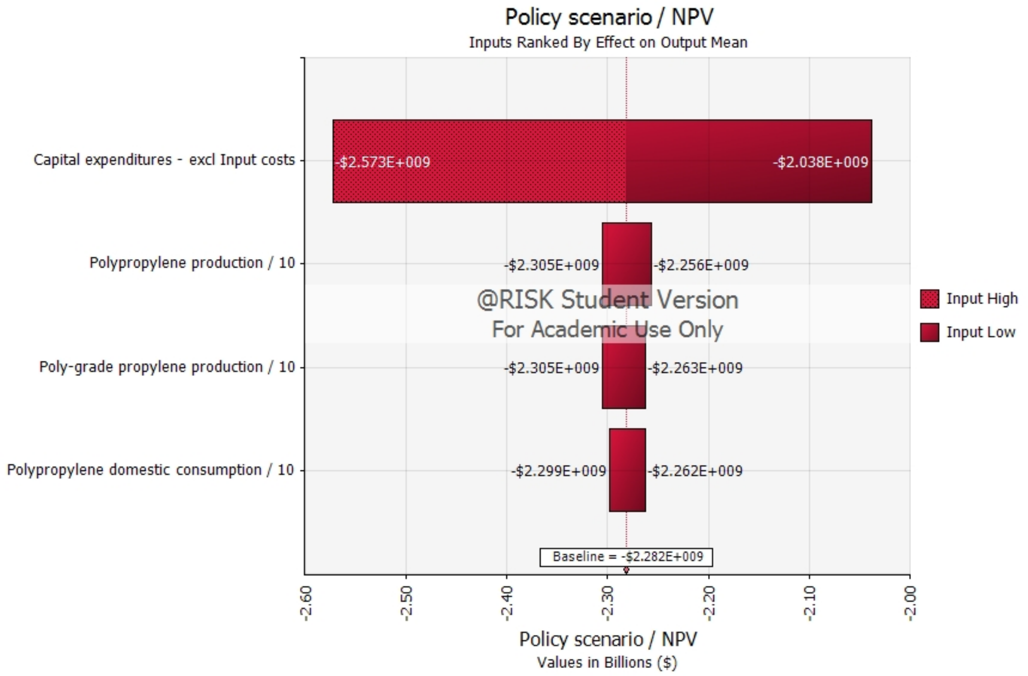


Figure 7.7: Sensitivity analysis of impact of inputs on NPV for policy scenario

investigated in this study, but these results suggest the need for similar research on the downstream industry to ensure better coordination of activities and outcomes of the policy.

7.2.3 Base and policy scenario NPV comparison

The base scenario without the policy will now be compared to the policy scenario of *cost plus 15%* to illustrate possible effects of developmental pricing on the polypropylene upstream value chain already discussed. In order to compare the two scenarios, the NPV for both was be compared as shown in Fig 7.8.

The model predicts that the developmental pricing policy scenario will result in a marked decrease in the $P_{NPV\geq 0}$ from 6.3% to 0.1%. The expected NPV value is predicted to decrease by approximately 96.1% from -US\$1.164 to -US\$2.283 in the ten years under investigation. This means that investors evaluating capital projects on capacity additions in the polypropylene value chain using a similar approach used in the current study might not find it promising to be profitable in a ten year period. This indicates that the polypropylene

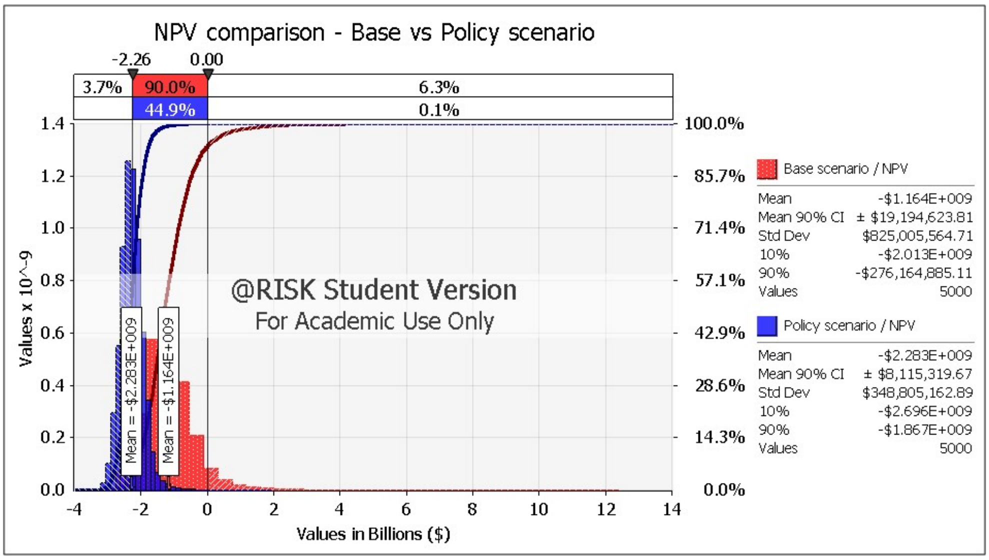
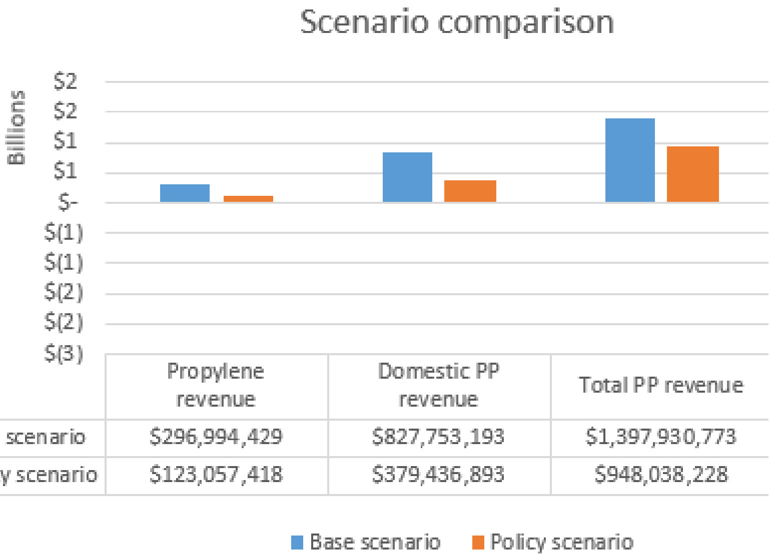


Figure 7.8: A comparison of probability distributions for NPV with policy and without policy.

value chain will not be attractive for future investment in capacity for the policy scenario compared to the base scenario where prices are responsive to global market trends.

A summary of revenue stream comparison for the base and policy scenario is shown in Fig 7.9.



	Propylene revenue	Domestic PP revenue	Total PP revenue
Base scenario	$296,994,429	$827,753,193	$1,397,930,773
Policy scenario	$123,057,418	$379,436,893	$948,038,228

Figure 7.9: A comparison of NPV *P90* values with policy and without policy.

The model estimates that the policy scenario would result in an overall decline in revenues from propylene and polypropylene. Total revenues from polypropylene are expected to drop by 32% from US$ 1 398 million to US$948 million as a result of domestic sales at prices below global markets prices. Revenues from domestic PP sales are similarly expected to drop by 54%, while propylene revenues will be reduced by 59%.

7.3 Decision tree model results

The NPV model predicts that under the policy scenario, there will be further reductions in expected revenue, resulting a decline in NPV for CAPEX employed up to 2014, for financial returns between 2015 and 2024. The dominant player in the polypropylene value chain in South Africa is SASOL. SASOL is an integrated company involved in the exploration and extraction of chemical feed-stocks, production of polymers such as polypropylene, acrylics, PVC and PE as well as other related polymer and chemical products.

It is not the intention of the current study to speculate on the industry's responsive strategies, or on the manner or motivations for the industry's future strategic shifts in the post-policy era, for a *cost-plus* pricing policy. On the contrary, this section attempts to shed more light on other revenue streams and cashflows for propylene value upstream. The change in revenue streams between the base and policy scenario will be highlighted, but due to lack of sufficient data, it was not be possible to explore how profitability will be affected. This approach was necessary to shed light on existing capacities in the remainder of the polypropylene value chain might be impacted by developmental pricing. This will be performed by allocating respective revenues in other activities of the value chain, including existing capacity in polypropylene and polypropylene. The contribution of these activities to revenues in the value chain will then be evaluated in order to understand the relative impact of developmental pricing on upstream revenue streams in the whole propylene value chain.

In order to allocate revenues to the various propylene products and their respective tiers, Section 6 Fig 6.7 in was used as a reference to construct the decision tree model.

Calculations for the revenue stream were performed as follows[1]:

1. First tier calculations (refinery grade propylene)
   (a) Probability $= \frac{\text{Contribution}}{\text{(Total industry consumption)}}$ x100
   (b) Revenue = -(Probability x Price x Production)
2. Second tier calculations (chemical/polymer grade propylene)
   (a) Probability $= \frac{\text{Capacity}}{\text{(Total tier capacity)}}$ x100
   (b) Revenue = (Tier 2 probability) x Production x Price
   + (Tier 1 revenue) x (Tier 2 Probability) x Production x Price
3. Third tier calculations (Final products or intermediates for other products)
   (a) Probability $= \frac{\text{Capacity}}{\text{Total tier capacity}}$ x 100
   (b) Revenue = (Tier 2 probability) x Production x Price
   + (Tier 1 revenue) x (Tier 2 probability) x Price x Production
4. Cumulative payoff $=\sum_{n=1}^{n=3} (T_n(revenue) \times T_n(probability))$; where T represents Tier

7.3.1 Revenue streams for base scenario

For both the base and policy scenarios, the optimum decision for the polypropylene branch was *FALSE*, based on the *most positive cumulative payoff decision rule* for each branch, which recommends selling polymer grade propylene over polypropylene manufacture. However, the prevailing strategy in the industry is polypropylene manufacture instead of selling polymer grade propylene.

In order to overcome the *highest cumulative payoff decision rule* restriction in the software, the *Force* branch option was enforced as illustrated in Fig 7.10 to obtain a more realistic model for both the base and policy scenarios. This was done to ensure that the polypropylene production branch was favored over the polymer propylene sales branch since the outcome is already known for the base scenario and assumed to stay the same for the policy scenario.

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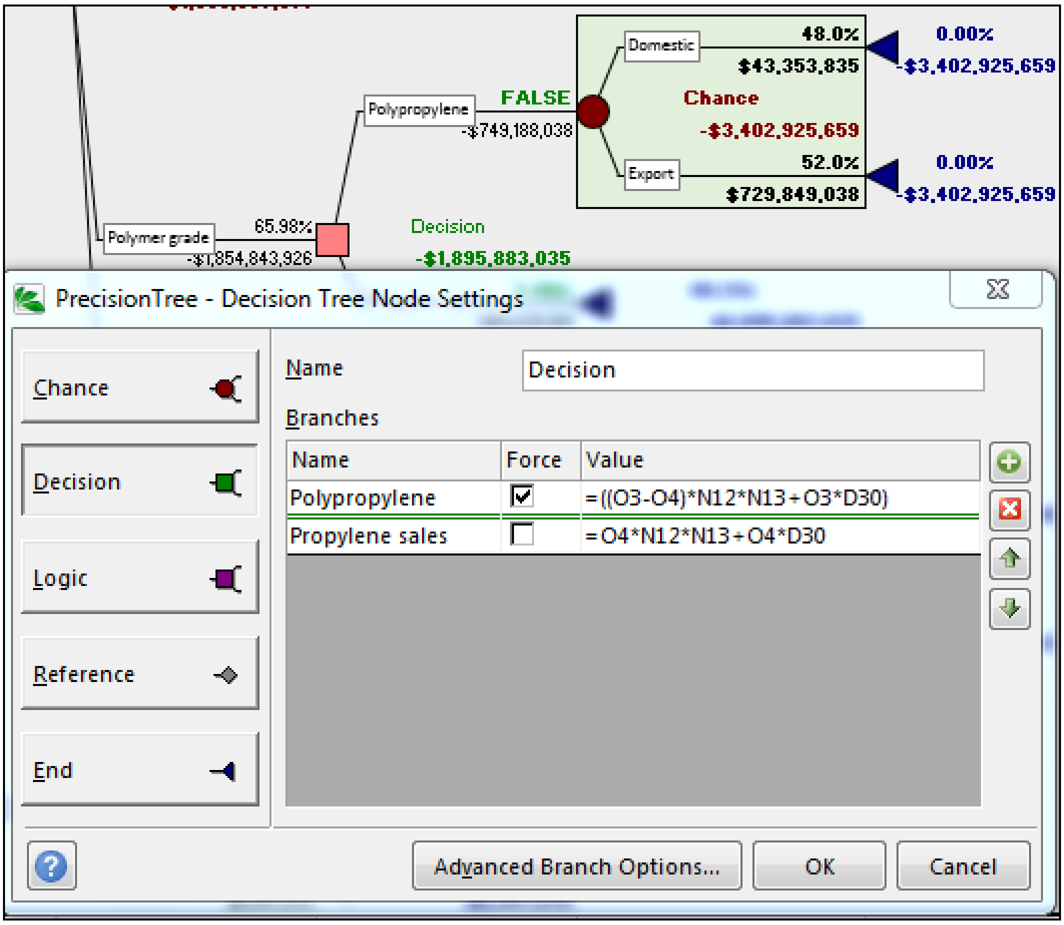
[1] All price and production values used were *P90 values* from *@Risk* outputs in the NPV model



Name: Decision

Branches

Name	Force	Value
Polypropylene	☑	=((O3-O4)*N12*N13+O3*D30)
Propylene sales	☐	=O4*N12*N13+O4*D30

Figure 7.10: Decision tree node settings for scenario without policy.

This observation could possibly be due to the integrated nature of operations for SASOL, the only producer of polymer grade propylene in the C/GTL branch of the value chain. As a result of the financial reporting practices by SASOL, it was not possible to accurately allocate financial and operational data from company reports for the polypropylene value chain. However, the reports suggest that cross-selling of products between operational units uses transfer pricing policies. This is likely to result in feedstocks being sold between operational units at below prevailing market prices, likely to cross-subsidise production activities for the different value chains. But since efforts to verify this were fruitless, this assertion was not be carried further and the logic for the model was then built by maintaining prices at global market value of products.

The risk of losses to revenues carried by upstream revenue streams for the base scenario were predicted to be approximately -US$2.435 billion for the propylene value chain as shown in Fig 7.11.

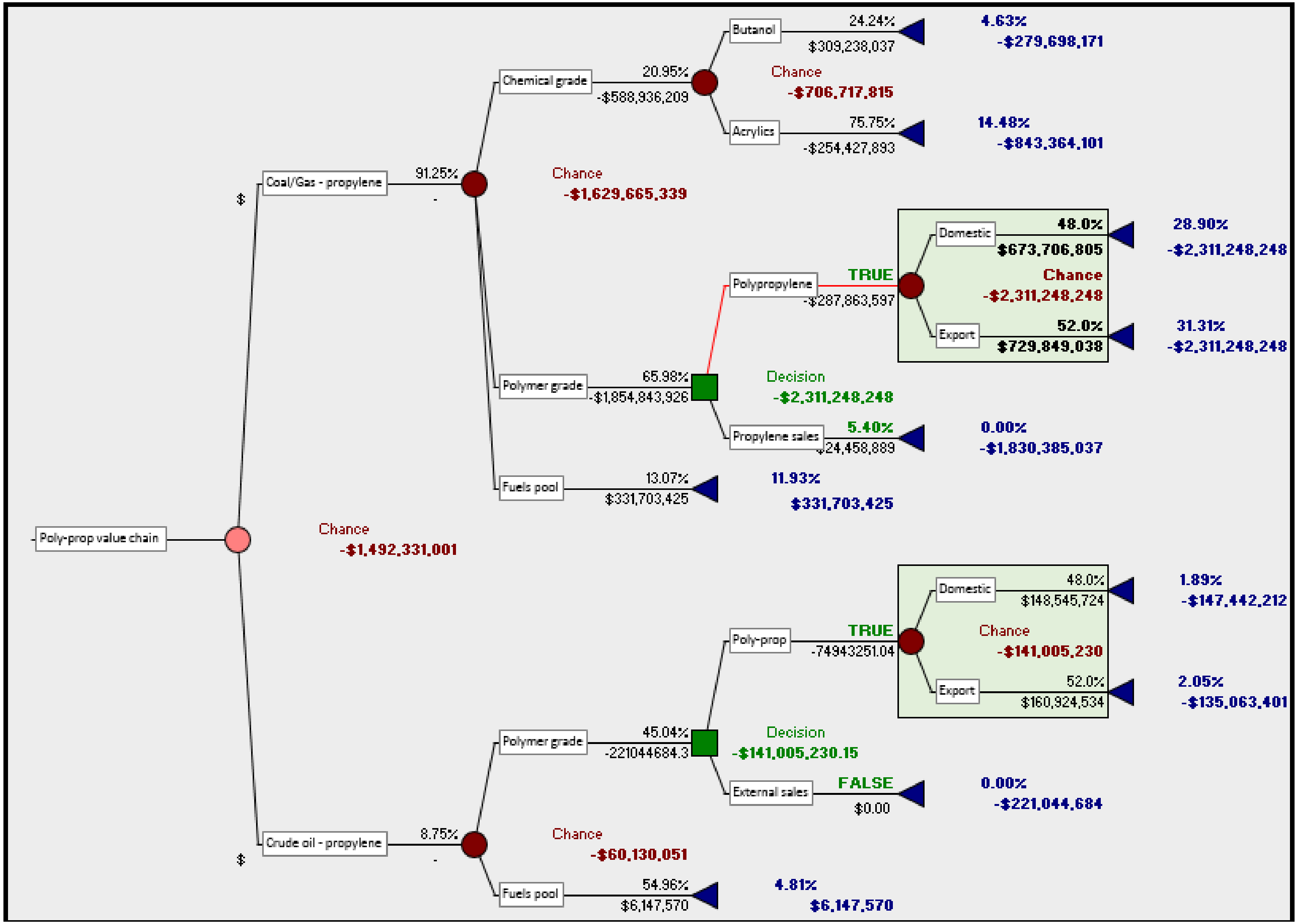


Figure 7.11: Decision tree showing possible revenue streams for the scenario without policy.

The risk of loss of revenues for the C/GTL branch of the value chain alone was predicted be approximately -US$2.311 billion, while risk of revenue losses for the oil refinery dependent branch of the value chain is predicted to amount to approximately -US$141 million for the base scenario. This translated to a revenue loss contribution of 96.44% and 3.56% for the C/GTL and oil refinery dependent branches of the value chain respectively. It is therefore apparent at this point that the C/GTL branch of the propylene value chain bears the lion share in risk of revenue loss for the propylene upstream value chain.

In both the C/GTL and crude oil branches of the value chain, the polypropylene sub-branch contributes the highest revenues compared to alternative products. Revenue contribution for polypropylene to the propylene value chain are equivalent to approximately 77.09% and 17.09% for the C/GTL and crude oil branches respectively. The C/GTL branch contributes higher revenues around US$1,737 billion compared to the crude oil branch, which contributes approximately US$309 million, possibly accounting for 83.42% and 16.38% of polypropylene revenues respectively.

Revenues from export sales are expected to be higher than those for domestic sales. Export revenues can be as high as US$890 million, while those from domestic sales could be as high as US$822 million. This suggests that polypropylene export revenues are the major source of revenue streams for the propylene value chain and will now be discussed further.

The high uncertainty of losses in revenues from export sales, combined with the fact that export sales constitute a bigger market for the polypropylene industry suggest that local suppliers of the industry would endeavor to optimise their revenues from domestic sales which are more guaranteed to realise positive revenue growth. However, according to industry reports, revenue growth through consumption or demand growth has not been realised for the domestic market for polypropylene, instead, an almost constant demand market is reported to prevail. This suggestion seems contrary to import data observed in Section 6.3. But the high imports reported could be due to high demand for polypropylene grades currently not manufactured by South African producers. In the current study, it was not possible to obtain data from downstream industries on polypropylene grades being used or from DTI on the grades imported compared to those manufactured locally and could be investigated in future research.

Since both the export and domestic markets do not seem to be individually capable of covering the full cost of raw materials and other operational costs, it is more likely that the industry will aim to manage both markets closely to realise optimum revenues. This has been observed to be the case for SASOL, which has been investing in developing the downstream industry locally, while at the same time continuing market penetration by expanding warehousing facilities in China to supply specialized wax products to satisfy their customers in the Asian market.

As previously noted, even though the decision analysis in this tree suggests that the optimal tree for the C/GTL branch is to sale polymer grade propylene and not produce polypropylene, the current situation in the industry makes polypropylene production more favorable than selling polymer grade propylene.

For the purpose of this study and due to lack of sufficient information and operational data for all players, it was satisfactory to assume that industry players are rational and have sound operational cost and risk management measures to avert these losses, thereby choosing to produce polypropylene. It was therefore decided that internal costing policies and practices would not be investigated for this study. However, for a more complete value chain analysis, it would be recommended that future studies could investigate how integrated companies like SASOL sustain profitability in highly volatile commodity markets, especially in the coal, oil and gas to chemicals value chains.

7.3.2 Revenue streams for the policy scenario

The decision tree model, shown in Fig 7.11, predicts that the overall risk of loss of revenue for the propylene value chain at *cost-plus 15%* developmental pricing would increase by 43.32% compared to the base scenario from approximately -US$1.492 billion to -US$2.138 billion for upstream production activities.

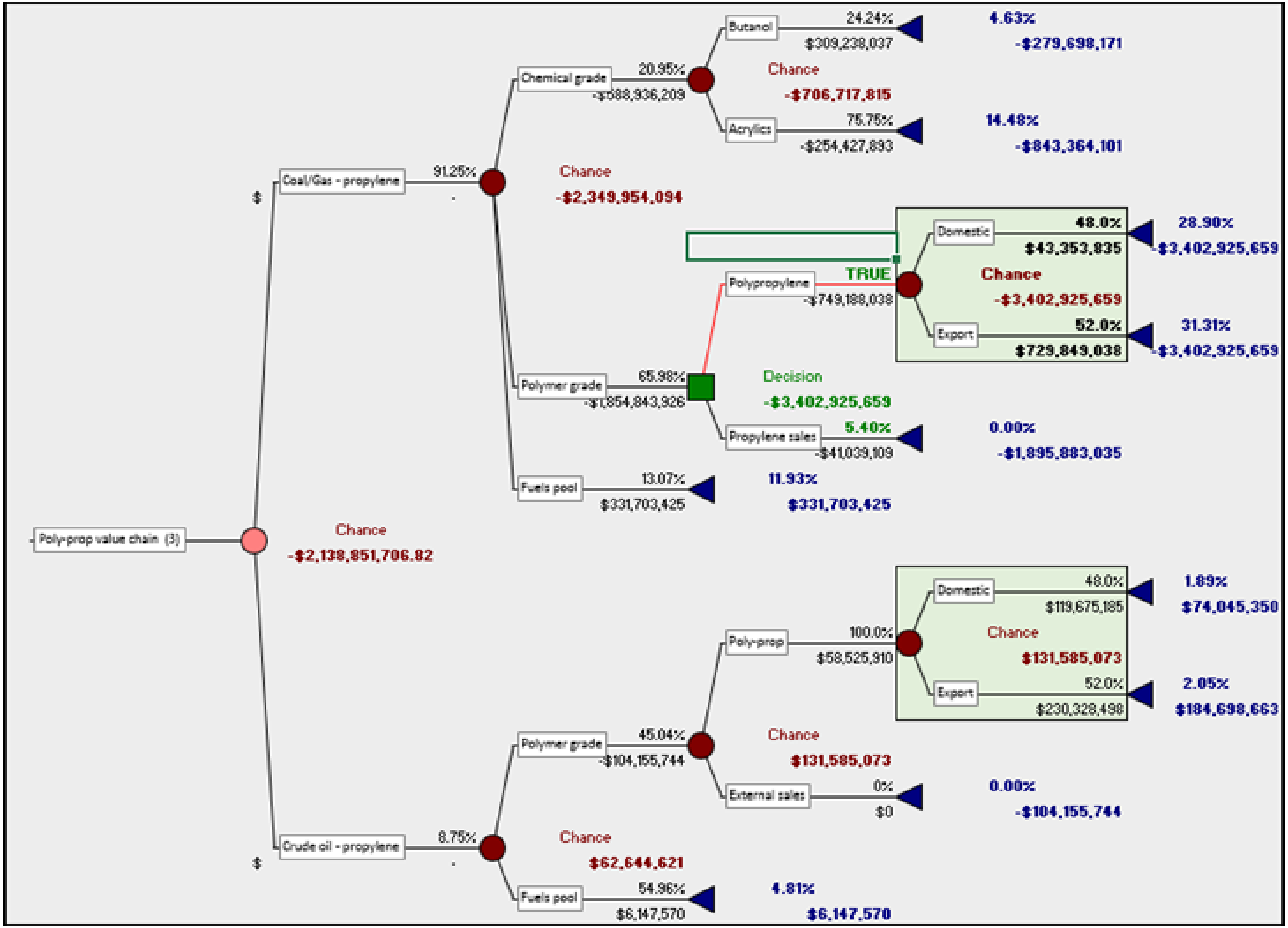
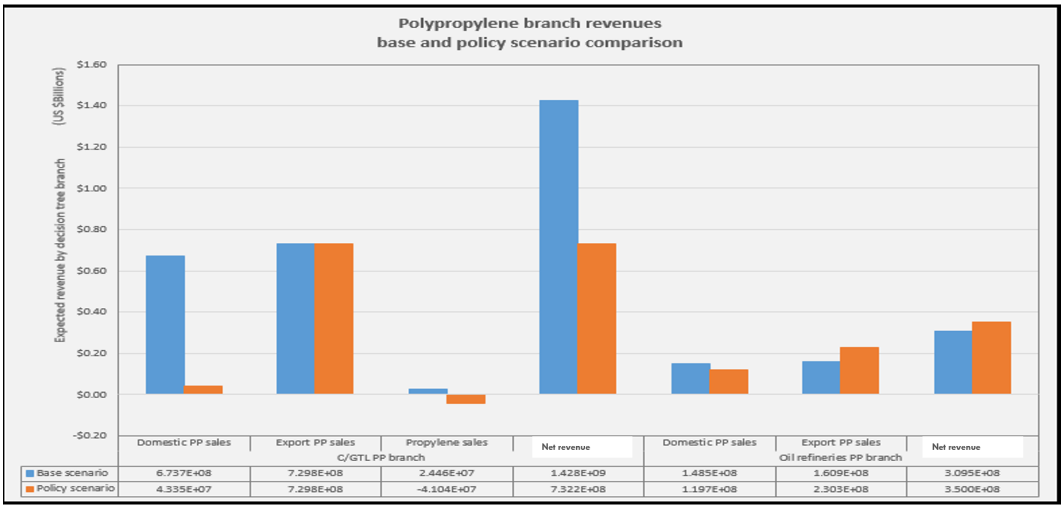


Figure 7.12: Decision tree showing possible revenue streams for the *cost-plus 15% pricing policy scenario*.

The risk of losses to revenues for the C/GTL branch of the value chain alone is approximated to increase by 44.2%from -US$1.629 to -US$2.349 billion. On the contrary, the risk of loss of revenue for the oil refinery dependent branch of the value chain is predicted to decrease by around 204.2% from -US$60.13 million to positive revenues around US$62.64 million under the *cost-plus 15% pricing* policy tested in this model. These finding suggests that the major beneficiary of developmental pricing would be the downstream industry and Safripol, the oil refinery dependent polypropylene producer in this value chain. This is mainly because Safripol, relies on the C/GTL branch through SASOL affiliated subsidiaries for more than 60% of it's polymer grade propylene since the propylene purification unit it operates at SAPREF can only supply less than half of Safripol's propylene requirements as discussed in Section 6.4.2.

7.3.3 Revenue streams comparison for the base and policy scenario

A summary of revenue comparison for the base and policy scenario in the polypropylene branch of the propylene value chain are shown in Fig 7.13.



	Domestic PP sales	Export PP sales	Propylene sales	Net revenue	Domestic PP sales	Export PP sales	Net revenue
	C/GTL PP branch				Oil refineries PP branch		
🟦 Base scenario	6.737E+08	7.298E+08	2.446E+07	1.428E+09	1.485E+08	1.609E+08	3.095E+08
🟧 Policy scenario	4.335E+07	7.298E+08	-4.104E+07	7.322E+08	1.197E+08	2.303E+08	3.500E+08

Figure 7.13: Comparison of PP revenue streams from decision tree results for the scenario with and without policy.

The major findings previously discussed are that the C/GTL branch of the value chain will bear the bigger share as far as risk of revenue loss is concerned. These predicted losses in revenues for the C/GTL branch and oil refinery dependent manufacturers are predicted to be largely due to diminished price levels at almost constant demand in local sales.

The model predicts that at *cost-plus 15%* developmental pricing, both domestic and export polypropylene revenues would still both carry an equally great risk of loss to revenues in the event that sales in the other market fail to materialize. The C/GTL polymer grade sub-branch belonging to SASOL and domestic polypropylene sales would suffer the most loss in revenue compared to the export markets. According to the model, revenue losses will only be due to price changes to the domestic market, while export revenue would remain unchanged for SASOL. On Safripol's part, revenues are likely to go up for both domestic and export markets, possibility due to reduction in feedstock costs. However, whether these input cost reductions will result in higher revenues for the downstream industry and the minority polypropylene producers or not solely depend on other internal operational and market efficiencies which are not the focus of this study.

One possible outcome suggested by these results is that further investments in the polypropylene value chain might become less profitable since expected revenues will decline. One area that could have disincentives for further investments is cost-cutting improvements, which might find operations becoming more integrated in order for costs to be shared, thereby inflating costs for the propylene value chain and subsequent prices to near market value. It can be argued from these results that mandatory supply of polymer grade propylene and polypropylene to other polypropylene producers and downstream converters, respectively, at cost-plus developmental pricing policy would result in major losses in revenue mainly for SASOL.

Summary of findings

The model predicts that the developmental pricing policy scenario will result in a 98.4% decrease in the $P_{NPV\geq 0}$ from 6.3% to 0.1%. The expected NPV value is predicted to decrease by approximately 96.1% from -US\$1.164 to -US\$2.283 for the policy compared to the base scenario. The evaluation of investment in capital projects on capacity additions in the polypropylene value chain using NPV might not find it promising to be profitable in a ten year policy tenure as evaluated in the current study.

Current findings require further research using more data on costs and other operational factors. However, evidence from NPV and IRR values suggest that short to medium profitability in the polypropylene industry does not promise to attract future investments in capacity additions under developmental pricing. The current study does not suggest that the polypropylene industry will not be profitable in the long-term since the policy might not be instituted beyond the 10 year period evaluated. In addition, other factors not investigated in the current study such as government investment incentive programs might result in the reduction of negative effects of the policy.

In order to evaluate alternative propylene usages that might become possible future investment opportunities upstream, a decision tree model was constructed from revenues of these activities using data generated from the NPV model under the base and policy scenario.

The model estimates that the policy scenario would result in an overall decline in revenues from propylene and polypropylene. Total revenues from polypropylene are expected to drop by 32% from US\$ 1 398 million to US\$948 million as a result of domestic sales at prices below global markets prices. Revenues from domestic PP sales are similarly expected to drop by 54%, while propylene revenues will be reduced by 59%.

The policy is likely to have the effect of transferring risk of losses in revenue from Safripol and polypropylene converters to SASOL, as both the propylene and polypropylene would now be available at a price less than half the current market price. However, as reported to the Parliamentary Committee on Trade and Industry on beneficiation by SASOL in 2014, the industry previously responded to import penetration by cheaper feedstocks by diverting propylene feedstocks from the fuel pool to lower the cost base.

Supplementary studies that might substantiate current findings are investigations on production capacity that would be required to absorb costs in the post-policy era and other production economics for the two major polypropylene producers. Similar studies can be conducted downstream to evaluate the extent of contribution to profitability by developmental pricing on the basis of the current model.

Chapter 8

Conclusions and recommendations

This chapter will summarise major findings of the current study to show that all goals set out for the project were successfully accomplished. Some limitations of the study will be discussed in order to make recommendations and identify opportunities for future studies based on outcomes of the current research.

Literature findings on industrial policy strategies for newly industrialising countries (NICs) outlined two main traditional approaches to industrialisation. The two strategies identified in literature were import substitution (IS) and export oriented (EO) industrialisation. The IS strategy was found to be through state intervention to protect,subsidise or regulate strategic companies or industries. The export oriented (EO) industrialisation strategy was found to follow liberalisation of capital markets and less state intervention, with markets dictating industrialisation priorities. The manner and timing for each of these strategies was found to be unrelated to global forces, but rather prioritised to meet national objectives by governments, with instances where both strategies were applied for different products within the same industry. However, the literature reviewed observed that the advent of globalisation and international trade have introduced complications for following these traditional approaches to industrialisation. This was found to be due to the participation of local industries in highly competitive global value chains that are governed independent of local market forces. The result of this finding was that policy analysis methods now have to take globalisation into account, keeping in mind the liberalisation of most global economies where products are traded.

Some of the industrial policy analysis methods were reviewed, but the ones found to be relevant to price regulation for globally trade-able products were successfully identified from literature. These methods include value chain analysis using the global value chain (GVC) framework as well as simulation studies, scenario analysis and discounted cash-flow models.

The next objective for the study was to map the polypropylene upstream value chain in order to qualitatively assess the relationship between global prices and capital project investment decisions in South Africa. This was successfully accomplished by compiling past industry data on product prices, production activities and historic capital expenditure (CAPEX) on capacity addition decision appraisals in the public domain. The polypropylene upstream value chain was successfully mapped, identifying value-adding activities and quantified the flow of materials from the apex of the extractive activities to the captive polypropylene manufacturing plants. Capital investment decisions were successfully assessed relative to product prices. It was found that CAPEX evaluations for capacity addition in the polypropylene upstream value chain in the past have been motivated by promising positive growth prospects in product price and demand growth potential of both local and global markets.

A model to evaluate attractiveness of the polypropylene upstream industry for future capital investments was then developed to predict future uncertainties in the industry before developmental pricing policy is instituted. Estimations of production and price uncertainties for possible future events in the polypropylene upstream value chain were modeled by fitting historical data to probability distributions using *@Risk* software from *Palisade*.

Monte-Carlo (MC) simulation was used to systematically sample random data points in order to account for uncertainties in estimating variables identified as key determinants of industry attractiveness during capital project evaluation. These variables were identified from industry and market reports. The simulation study successfully evaluated NPV values for CAPEX projects undertaken in the polypropylene upstream value chain between 2004 and 2014 for the base scenario without the policy. The model was successfully adapted to evaluate future returns on CAPEX similar to those appraised in the last 10 years for the polypropylene upstream value chain using discounted cash-flows. The $P_{NPV \geq 0}$ was determined to be approximately 6.3% for the base scenario compared to 0.1% for the policy scenario using a discount rate of 12.5% over a ten year period from 2015 to 2024.

The expected value in the *cost-plus 15%* developmental pricing policy scenario was found to be significantly lower than the base scenario in the same period. The expected value obtained for the *cost-plus 15%* was approximately -US$2.283 billion compared to -US$1.164 for the base scenario. This suggests that the policy scenario might result in various undesirable effects related to poor prospects for future returns. The possible effect of this is that the polypropylene upstream industry in South Africa might become unattractive for future investments in capital projects. It can be concluded that the approach used in this paper can be used to investigate possible effects of developmental pricing policy on attractiveness for future investment in polypropylene upstream value chain capital projects in South Africa.

8.1 Recommendations

The shift in technologies globally from oil to renewable chemical feedstocks and other cheaper alternatives might result in loss of market share for coal derived polymers. The study therefore recommends the strategic focus in the chemical sector, including the polypropylene and plastics industry, to explore development of new technologies and value chains upstream to reduce over-reliance on coal and oil as feedstocks. Findings from the current study suggest that strategies to develop the polypropylene and plastics sector could also evaluate alternative propylene usages as priority areas for production of high value, utility products in the global market.

8.2 Study limitations

Findings of the current study have demonstrated the usefulness of quantitative techniques to evaluate possible impacts of industrial policies. These findings should not be viewed as conclusive, but rather suggestive of the need for further studies to ascertain other possible effects of industrial policies like developmental pricing. In addition, due to limited availability of data, only *cost-plus* pricing formula could be investigated in the current study. It would be recommended to investigate other developmental pricing approaches.

Some of the limitations of the current model are that it covers a limited number of uncertain variables due to a unavailability or lack of sufficient data due to unwillingness by organisations to disclose financially sensitive information. The current study was limited to only investigating uncertainties associated with price and production risks relative to CAPEX and DCF due to lack of sufficient data to model with. This was related to difficulties encountered in obtaining data on other production economics such as supply and demand, minimum efficient scale, cost curve, production possibility frontier and opportunity costs. The ideal model would be a more robust one encompassing more uncertainties in the industry like interest rates on capital loans, foreign currency fluctuations, inflation rate, labour disputes and import penetration, to name a few.

Access to downstream industry databases proved to be difficult, in addition to the diverse nature of operations in this part of the value chain. This limited the study to upstream value chain activities, resulting in the model accounting less for elasticity in demand due to capacity downstream as well buying decisions, with respect to availability of cheaper suppliers globally. Capacity in the downstream value chain were therefore not investigated to ensure they can absorb upstream overcapacity to understand how upstream investments take these factors into consideration when making decisions. The level of skills development, local innovation, research and development systems downstream could have also given more insight on how upstream activities are coordinated to downstream industries to leverage on local capabilities for expansion of the industry.

8.3 Future work and outlook

Further study is recommended to carry out similar quantitative studies with other developmental pricing formulas, including influence of global demand and supply variability developmental pricing effects. Future work on developmental pricing can incorporate currency exchange rates risks and risks associated with tariffs in the global value chain and how all these factors influence decisions in the supply chain. Some of the limitations in this study point out the importance of investigations into transfer pricing methodologies and how these can be incorprated into industrial policy. These studies can assist policy makers to anticipate and mitigate the influence of companies with integrated operations and those participating intensively in global value chains, including international operations.

Future studies can develop industrial policy strategies based on incentive regulation instead of price regulation in order to motivate organisations to be more innovative on process improvements, capacity addition and cost reduction in order to increase competition for lower prices. Another area that can contribute to further investigation of developmental pricing policy appraisal could focus on how industry development can also be focused on upstream capacity building to supply specialty polymers and polymer grades required downstream that are currently being imported in large volumes, offsetting the trade balance due to exports.

Appendices

Appendix A

Economic development strategies

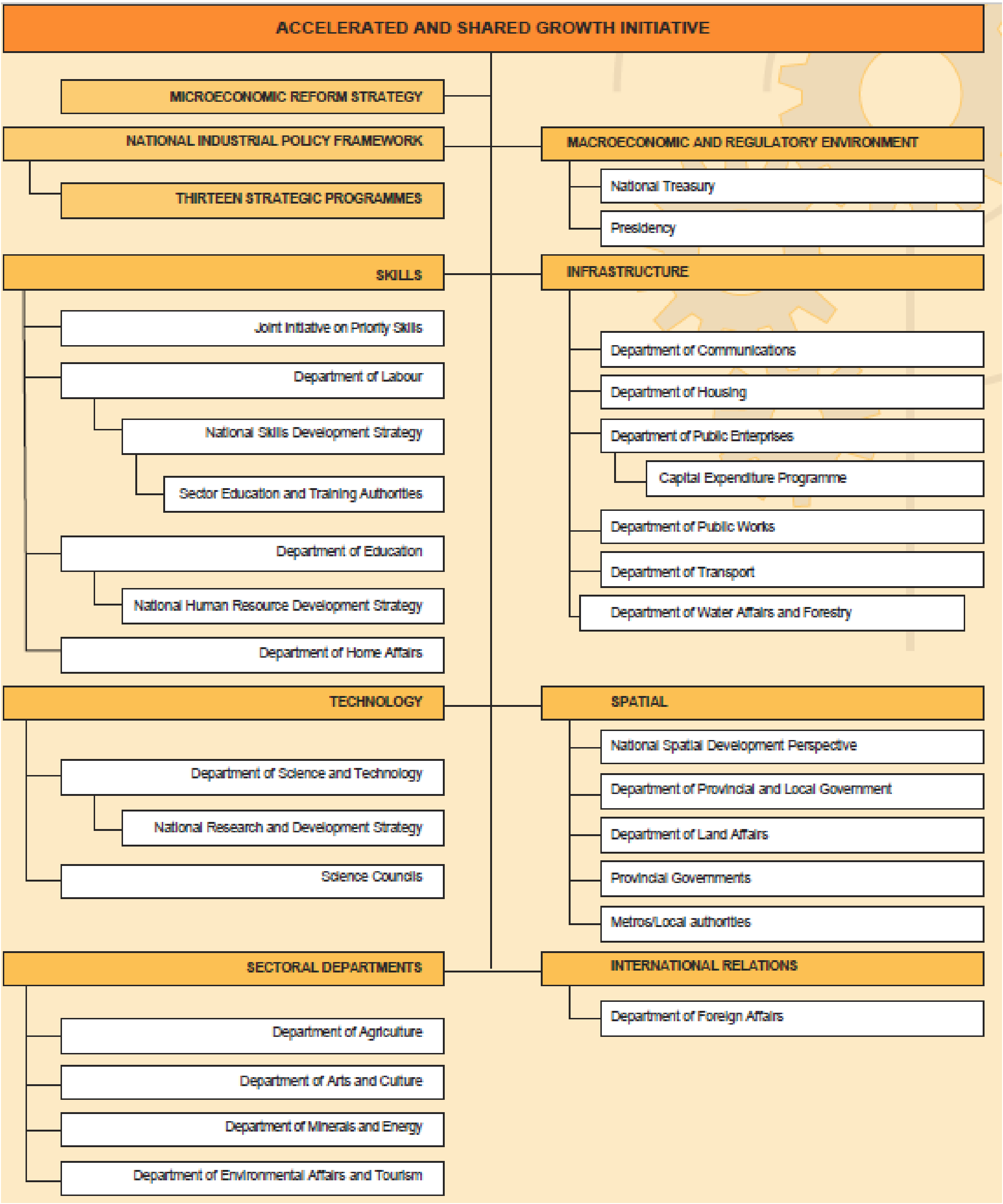


Figure A.1: A summary of DTI's inter-departmental proposed by NIPF policy initiatives. Source: DTI (2007)

Appendix B

History of global plastics industry

Table B.1: A summary of major historical developments in the polymer and plastics industries

Period	Polymer (Discovery &/or Commercial plastic)	Major commercial applications and uses	Scientist/ Company	Country
1839	Polystyrene (PS)	No commercial value at the time	E.Simon & H.Staudinger	Germany
1869	Celluloid	Substitute for tortoiseshell, horn, linen, and ivory	J.W Hyatt	TBA
1907	Phenol formaldehyde (Bakelite)	Substitute for shellac (electrical insulator)	L.Bakelite	USA
1910	Steam cracker	Extraction of ethylene,propylene & butadiene from petroleum	Unknown	Unknown
1920/ 1922 - 1930	Polystyrene (PS)	Packaging foams & plastic boxes	BASF	Germany
1926	Polyvinylchloride(PVC)	Window and door profiles, pipes & cable duct. Packaging film.Insulation & sheathing for wire & cables	W.L Semon (B.F.Goodrich Company)	USA
1928/ 1935-1939	Polyamides (PA)-(Nylon)	Fibers, textiles, brush bristles & ropes	W.Carothers (DuPont)	USA
1931-1939	Polythylene (PE)	Supermarket bags, plastic bottles, elastics bands	R.Gibson&E.Fawcett (Imperial Chemical Industries)	England
1930-1940	Polymethyl methacrylate (PMMA) (Perspex)	Cast sheets (baths &sanitary-ware,illuminated signs, glass-ware, automotive &domestic lighting,dentures, eye-ware and bone cements	Imperial Chemical Industries	England
1933	Low Density Polyethylene (LDPE)	Film packaging, electrical insulation, milk carton lining buckets, bowls, squeeze bottles & flexible water pipes	Imperial Chemical Industries	England
1933	Polyvinylidene Chloride (PVDC)	Food packaging. Pipes, frames, flooring & shower curtains	R.Wiley (The Dow Chemical Company)	USA
1937	Polyurethane (PU)	Foam (cushions,mattresses,furniture &automotives),thermal insulation,automotive coatings	O.Bayer(Bayer company)	Germany

Continued on next page

Period	**Polymer (Discovery &/or Commercial plastic)**	**Major commercial applications and uses**	**Scientist/Company**	**Country**
1941	Polyethylene terephthalate (PET)	Bottles (carbonated drinks) & plastic films	R.Whinfield &J.Dickson (Calico Printer's Association)	England
Period	Polymer (Discovery &/or Commercial plastic)	Major uses	Scientist/Company	Country
1945 - 1950	Polyester (PES)	Fibers and textiles	J.Winfield & J.Dickson (DuPont)	USA
1948 - 1954	Acrylonitrile Butadiene Styrene Copolymer (ABS)	Electronic equipment cases (televisions,computers, printers, mouses, keyboards etc)	Borg Warner Corporation	Germany
1951	High Density Polyethylene (HDPE)	Household detergent/chemical containers, dustbins,crates,industrial packaging and pipes	P.Hogan & R.Banks (Phillips Petroleum)	USA
1951	Polypropylene (PP)	Bottle caps, beverage & food containers, appliances, automotive components	Uncertain	Uncertain
1954	Foamed Polystyrene(PS) (Styrofoam)	Insulation foam, (closed cavity walls, roofs, floor insulation), road construction, packaging (food, cushioning electronics,protective wear)	R.McIntire (at The Dow Chemical Company)	USA
1955- 1957	Polycarbonate (PC)	Compact discs, eyeglasses, security windows, helmets, traffic lights, lenses, car interiors, and parts of mobile phones	H.Schnell(Bayer) &D. Fox(GE Polycarbonate)	Germany
1978- 1980	Linear Low Density Polyethylene (LLDPE)	Outdoor plastic furniture and food packaging	Uncertain	Uncertain
1990	Polyhydroxybutyrate (PHB)	Wrap foods, paper coatings,kitchen ware, medical use (sutures, gauzes & coatings for medication)	Imperial Chemical Industries	England
2000	Metallocene Linear Low Density Polyethylene(mLLDPE)	Deep freeze packaging and food wraps	patent disputed (Univation Technologies(Exxon Corp-Union Carbide Corp JV) & Dow Chemical Company	USA

Continued on next page

Period	**Polymer (Discovery &/or Commercial plastic)**	**Major commercial applications and uses**	**Scientist/Company**	**Country**
2000 (patented 1985)	Clay/nylon nanocomposite	A.Okada &team	Toyota Central Research & Development Lab Inc.	Japan
2001	Clay/Popylpropylene nanocomposite	Improve performance of materials for food packaging, structural, chemical, electrical/electronic, and medical fields.	Montell(Now Basell),Southern Clay Products & General Motors	USA
1997	3D Printing manufacturing	Body parts of PMMA	Aeromet	Unknown
2007 (1989)	Nano-molding	Lithographic engraving, electro-plating,printed circuits,car parts,prototypes	Karlsruhe Institute of Technology	Germany

B.1 Global trends in polymer/plastics industries

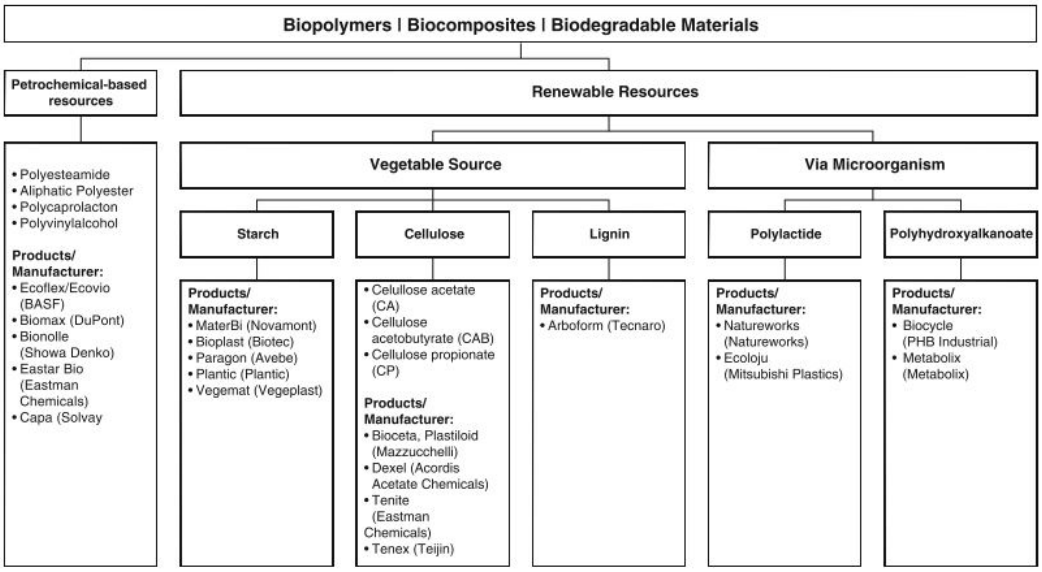
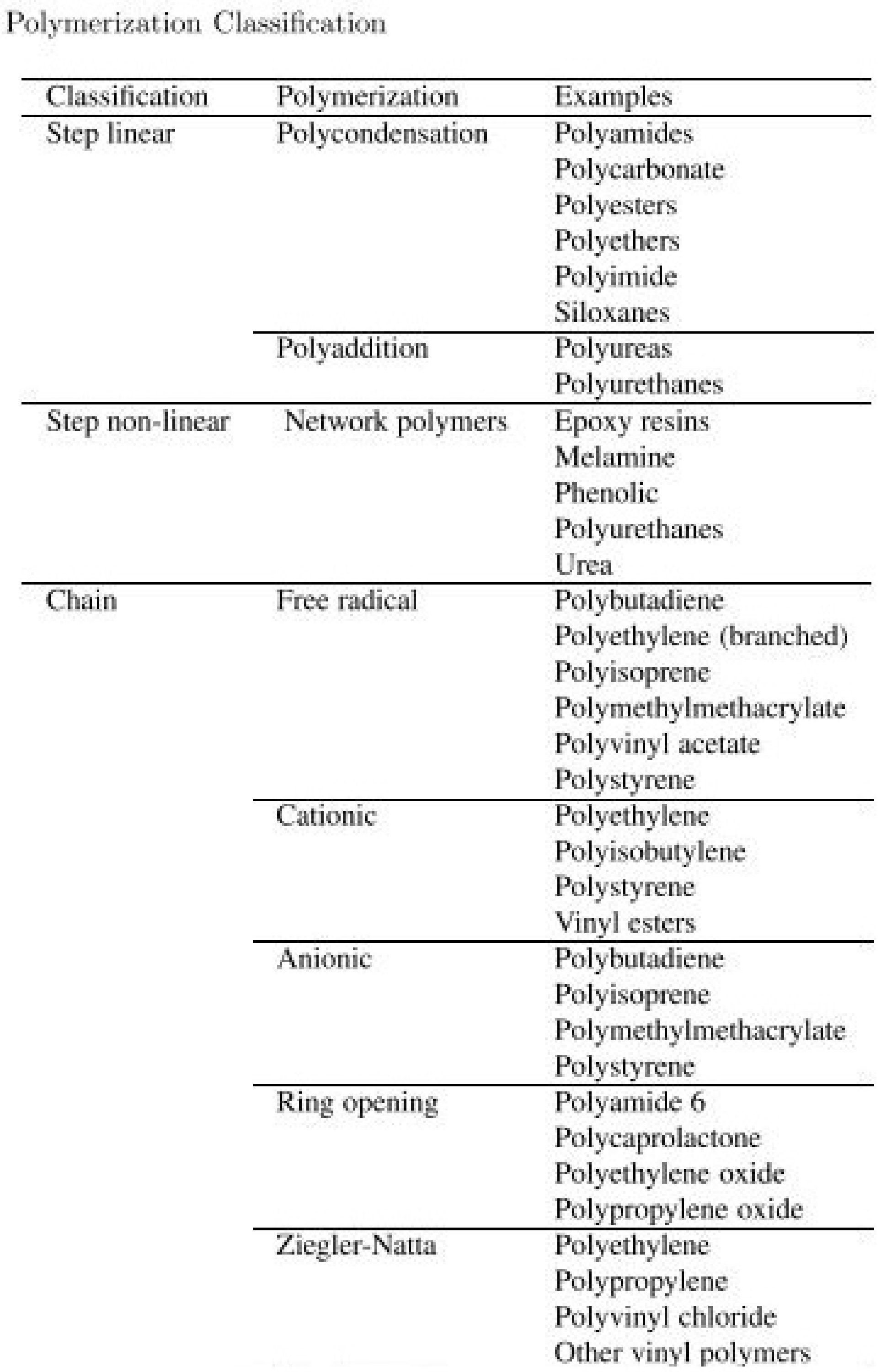


Figure B.1: Examples of commercial biodegradable polymers. Source : Eyerer *et al.* (2010)

B.2 Common polymerisation reaction



Polymerization Classification

Classification	Polymerization	Examples
Step linear	Polycondensation	Polyamides Polycarbonate Polyesters Polyethers Polyimide Siloxanes
	Polyaddition	Polyureas Polyurethanes
Step non-linear	Network polymers	Epoxy resins Melamine Phenolic Polyurethanes Urea
Chain	Free radical	Polybutadiene Polyethylene (branched) Polyisoprene Polymethylmethacrylate Polyvinyl acetate Polystyrene
	Cationic	Polyethylene Polyisobutylene Polystyrene Vinyl esters
	Anionic	Polybutadiene Polyisoprene Polymethylmethacrylate Polystyrene
	Ring opening	Polyamide 6 Polycaprolactone Polyethylene oxide Polypropylene oxide
	Ziegler-Natta	Polyethylene Polypropylene Polyvinyl chloride Other vinyl polymers

Figure B.2: Summary of common plastics and polymerization reactions. Source : (Subramanian, 2015, pp.9)

Appendix C

Incentive regulation

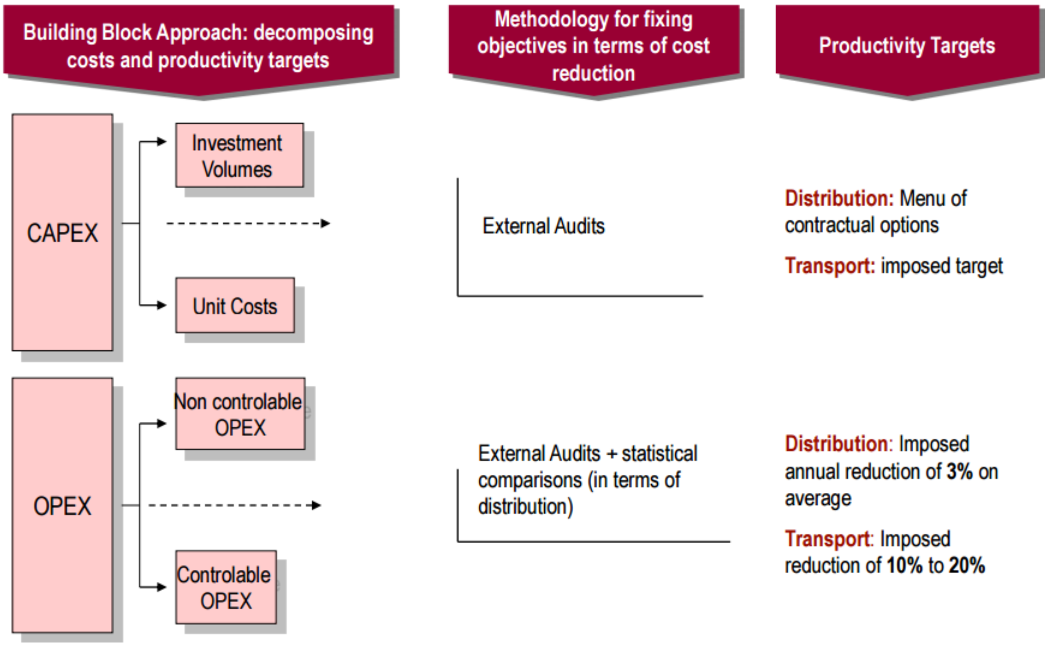


Figure C.1: An illustration of incentive regulation cost allocation. Source: Jacobzone (2014)

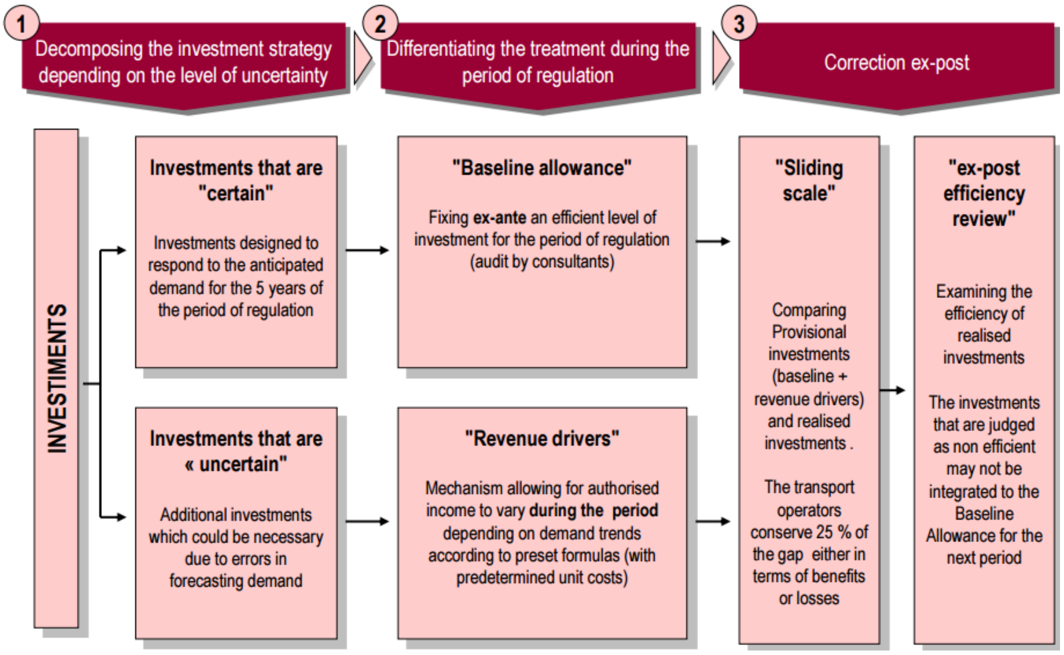
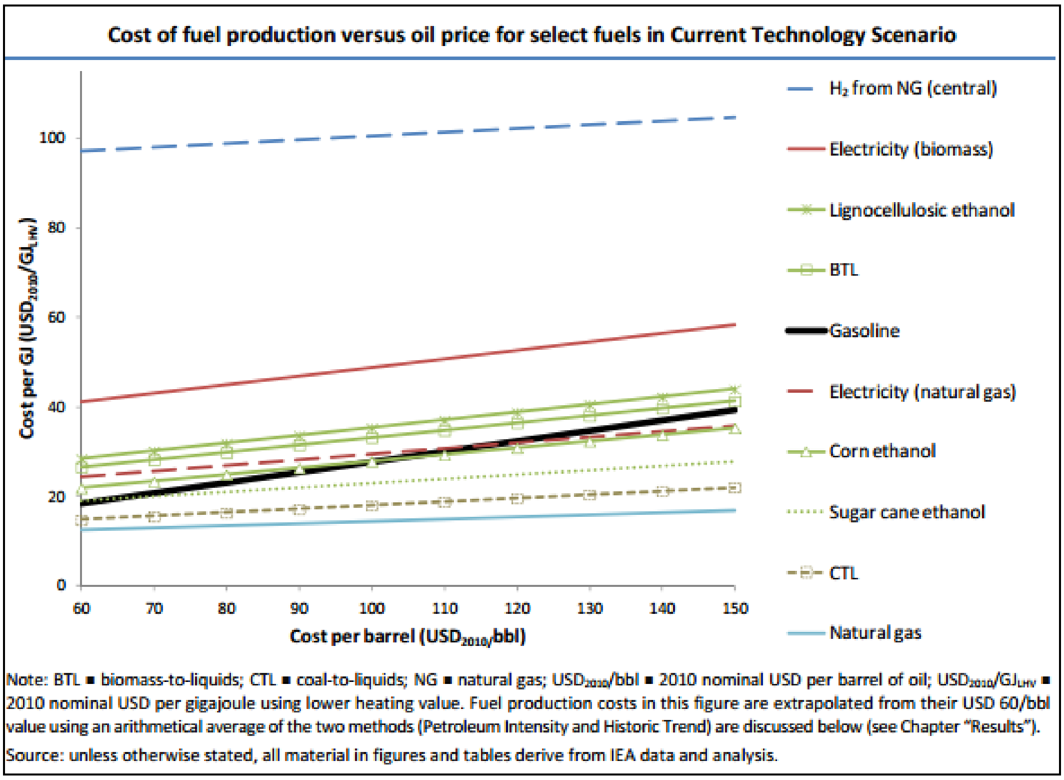


Figure C.2: An illustration of incentive regulation investment compensation criteria. Source: Jacobzone (2014)

Appendix D

GVC analysis

D.1 Alternative fuel production cost comparison



Note: BTL ▪ biomass-to-liquids; CTL ▪ coal-to-liquids; NG ▪ natural gas; USD_{2010}/bbl ▪ 2010 nominal USD per barrel of oil; USD_{2010}/GJ_{LHV} ▪ 2010 nominal USD per gigajoule using lower heating value. Fuel production costs in this figure are extrapolated from their USD 60/bbl value using an arithmetical average of the two methods (Petroleum Intensity and Historic Trend) are discussed below (see Chapter "Results").

Source: unless otherwise stated, all material in figures and tables derive from IEA data and analysis.

Figure D.1: Alternative fuel production cost comparison by production technology only. Source: IEA (2015*b*).

D.2 Global propylene production technology projections

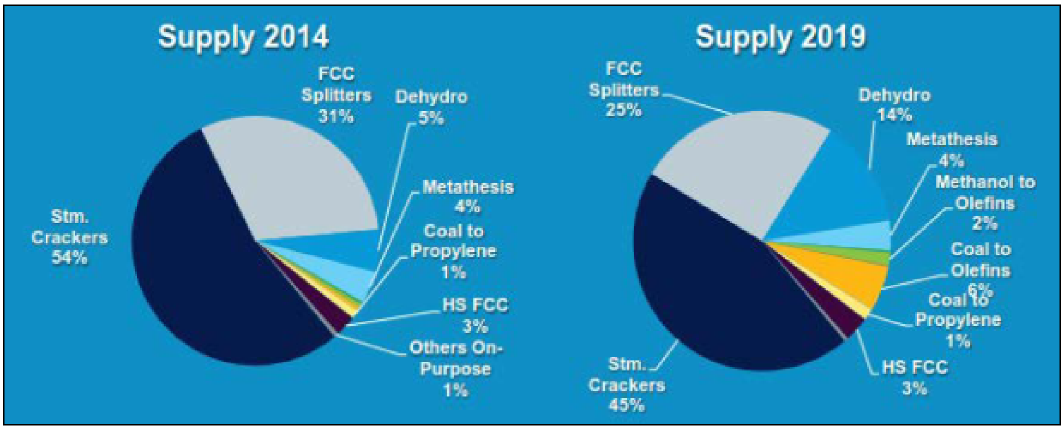


Figure D.2: Global estimates of propylene production technologies by 2014. Source: Wattanakarunwong (2015)

Where:

Stm. Crackers - Steam Cracking. Conventional thermal cracking of naphtha (oil refinery by-product).

Dehydro - Propane Dehydrogenation process to produce propylene and gasoline products. Propane can also be from natural gas.

Metathesis - Double bond transfer reactions from butylene (C_4) to ethylene (C_2), producing gasoline and propylene.

HS FCC - High Severity Fluidized Catalytic Cracking of crude oil.

Coal to Propylene - Coal gasification followed by direct liquefaction. (hydrogenation) or Fischer-Tropsch synthesis, indirect liquefaction (hydrous pyrolysis) to petroleum equivalent products.

Methanol to Olefins - Co-production of ethylene and propylene.

FCC Splitters - Fluidized Catalytic Cracking Refinery splitter. Splitter is a depropaniser unit to separate propylene and propane from

D.3 Capacity additions to Coal-To-Olefins (CTO) plants in China comparable to SASOL's C/GTL

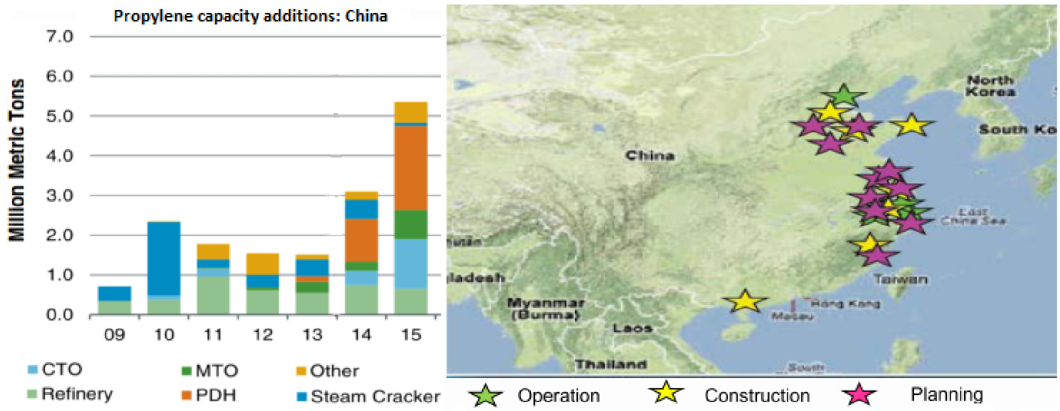


Figure D.3: Estimated capacity additions to coal to olefins (C/GTL) and other on-purpose propylene production plants in China. Source:Wattanakarunwong (2015).

D.4 North East Asia propylene production technology cost comparison

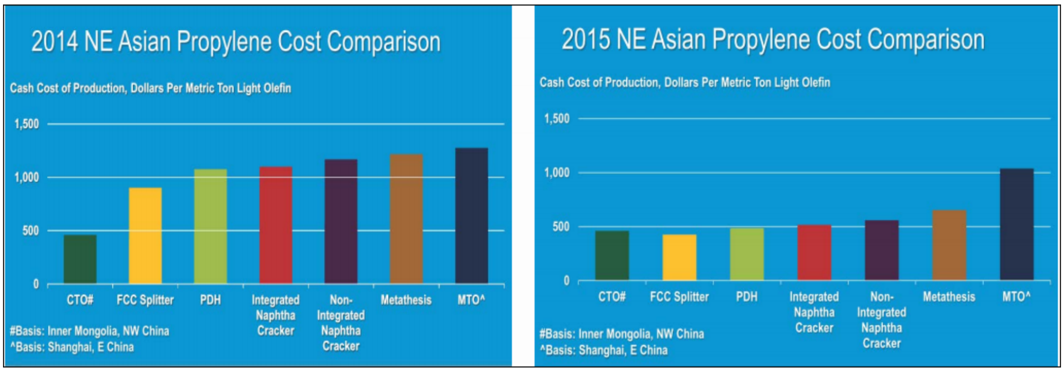
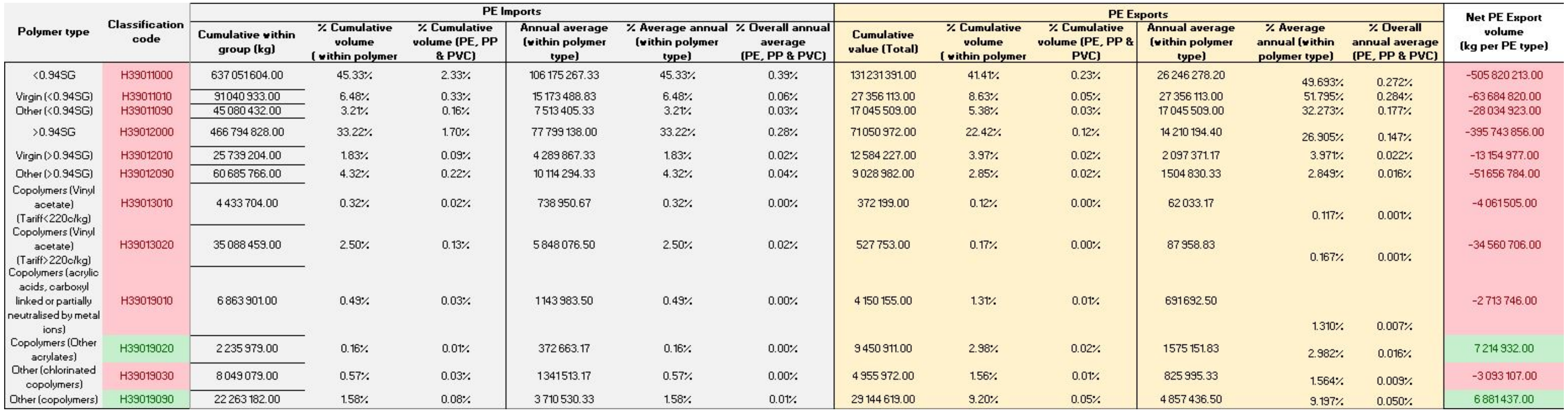


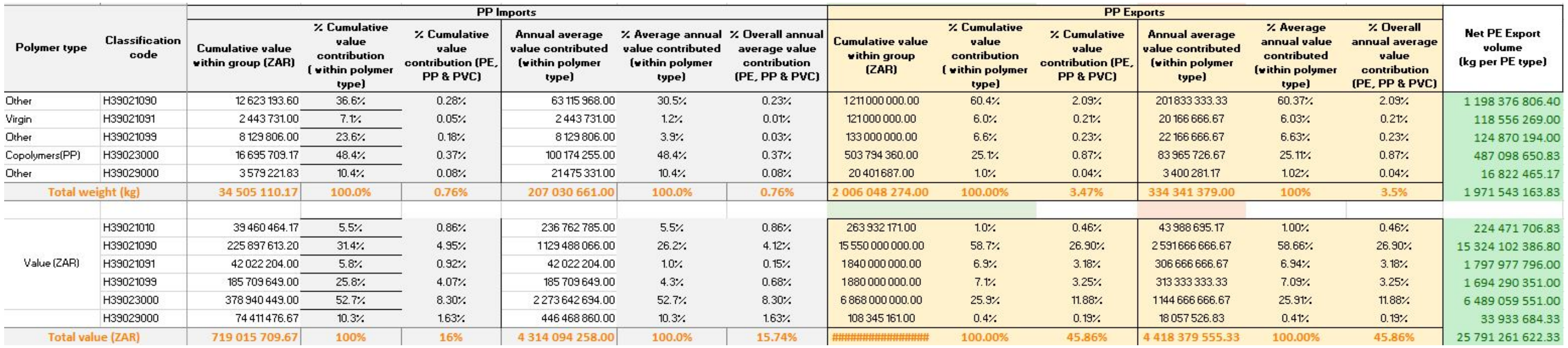
Figure D.4: Propylene production cost comparison by production technology only. Source: Wattanakarunwong (2015).

D.5 Upstream PE input/output: South Africa



Polymer type	Classification code	PE Imports						PE Exports						Net PE Export volume (kg per PE type)
		Cumulative within group (kg)	% Cumulative volume (within polymer	% Cumulative volume (PE, PP & PVC)	Annual average (within polymer type)	% Average annual (within polymer type)	% Overall annual average (PE, PP & PVC)	Cumulative value (Total)	% Cumulative volume (within polymer	% Cumulative volume (PE, PP & PVC)	Annual average (within polymer type)	% Average annual (within polymer type)	% Overall annual average (PE, PP & PVC)	
<0.94SG	H39011000	637 051 604.00	45.33%	2.33%	106 175 267.33	45.33%	0.39%	131 231 391.00	41.41%	0.23%	26 246 278.20	49.693%	0.272%	-505 820 213.00
Virgin (<0.94SG)	H39011010	91 040 933.00	6.48%	0.33%	15 173 488.83	6.48%	0.06%	27 356 113.00	8.63%	0.05%	27 356 113.00	51.795%	0.284%	-63 684 820.00
Other (<0.94SG)	H39011090	45 080 432.00	3.21%	0.16%	7 513 405.33	3.21%	0.03%	17 045 509.00	5.38%	0.03%	17 045 509.00	32.273%	0.177%	-28 034 923.00
>0.94SG	H39012000	466 794 828.00	33.22%	1.70%	77 799 138.00	33.22%	0.28%	71 050 972.00	22.42%	0.12%	14 210 194.40	26.905%	0.147%	-395 743 856.00
Virgin (>0.94SG)	H39012010	25 739 204.00	1.83%	0.09%	4 289 867.33	1.83%	0.02%	12 584 227.00	3.97%	0.02%	2 097 371.17	3.971%	0.022%	-13 154 977.00
Other (>0.94SG)	H39012090	60 685 766.00	4.32%	0.22%	10 114 294.33	4.32%	0.04%	9 028 982.00	2.85%	0.02%	1504 830.33	2.849%	0.016%	-51 656 784.00
Copolymers (Vinyl acetate) (Tariff<220c/kg)	H39013010	4 433 704.00	0.32%	0.02%	738 950.67	0.32%	0.00%	372 199.00	0.12%	0.00%	62 033.17	0.117%	0.001%	-4 061 505.00
Copolymers (Vinyl acetate) (Tariff>220c/kg)	H39013020	35 088 459.00	2.50%	0.13%	5 848 076.50	2.50%	0.02%	527 753.00	0.17%	0.00%	87 958.83	0.167%	0.001%	-34 560 706.00
Copolymers (acrylic acids, carboxyl linked or partially neutralised by metal ions)	H39019010	6 863 901.00	0.49%	0.03%	1 143 983.50	0.49%	0.00%	4 150 155.00	1.31%	0.01%	691 692.50	1.310%	0.007%	-2 713 746.00
Copolymers (Other acrylates)	H39019020	2 235 979.00	0.16%	0.01%	372 663.17	0.16%	0.00%	9 450 911.00	2.98%	0.02%	1575 151.83	2.982%	0.016%	7 214 932.00
Other (chlorinated copolymers)	H39019030	8 049 079.00	0.57%	0.03%	1 341 513.17	0.57%	0.00%	4 955 972.00	1.56%	0.01%	825 995.33	1.564%	0.009%	-3 093 107.00
Other (copolymers)	H39019090	22 263 182.00	1.58%	0.08%	3 710 530.33	1.58%	0.01%	29 144 619.00	9.20%	0.05%	4 857 436.50	9.197%	0.050%	6 881 437.00

Figure D.5: PE data used to calculate trade balances for different PE types between 2010 and 2015. Data source: Quantec (2016)



		PP Imports						PP Exports						Net PE Export volume (kg per PE type)
Polymer type	Classification code	Cumulative value within group (ZAR)	% Cumulative value contribution (within polymer type)	% Cumulative value contribution (PE, PP & PVC)	Annual average value contributed (within polymer type)	% Average annual value contributed (within polymer type)	% Overall annual average value contribution (PE, PP & PVC)	Cumulative value within group (ZAR)	% Cumulative value contribution (within polymer type)	% Cumulative value contribution (PE, PP & PVC)	Annual average value contributed (within polymer type)	% Average annual value contributed (within polymer type)	% Overall annual average value contribution (PE, PP & PVC)	
Other	H39021090	12 623 193.60	36.6%	0.28%	63 115 968.00	30.5%	0.23%	1211 000 000.00	60.4%	2.09%	201 833 333.33	60.37%	2.09%	1 198 376 806.40
Virgin	H39021091	2 443 731.00	7.1%	0.05%	2 443 731.00	1.2%	0.01%	121 000 000.00	6.0%	0.21%	20 166 666.67	6.03%	0.21%	118 556 269.00
Other	H39021099	8 129 806.00	23.6%	0.18%	8 129 806.00	3.9%	0.03%	133 000 000.00	6.6%	0.23%	22 166 666.67	6.63%	0.23%	124 870 194.00
Copolymers(PP)	H39023000	16 695 709.17	48.4%	0.37%	100 174 255.00	48.4%	0.37%	503 794 360.00	25.1%	0.87%	83 965 726.67	25.11%	0.87%	487 098 650.83
Other	H39029000	3 579 221.83	10.4%	0.08%	21 475 331.00	10.4%	0.08%	20 401 687.00	1.0%	0.04%	3 400 281.17	1.02%	0.04%	16 822 465.17
Total weight (kg)		34 505 110.17	100.0%	0.76%	207 030 661.00	100.0%	0.76%	2 006 048 274.00	100.00%	3.47%	334 341 379.00	100%	3.5%	1 971 543 163.83
Value (ZAR)	H39021010	39 460 464.17	5.5%	0.86%	236 762 785.00	5.5%	0.86%	263 932 171.00	1.0%	0.46%	43 988 695.17	1.00%	0.46%	224 471 706.83
	H39021090	225 897 613.20	31.4%	4.95%	1 129 488 066.00	26.2%	4.12%	15 550 000 000.00	58.7%	26.90%	2 591 666 666.67	58.66%	26.90%	15 324 102 386.80
	H39021091	42 022 204.00	5.8%	0.92%	42 022 204.00	1.0%	0.15%	1840 000 000.00	6.9%	3.18%	306 666 666.67	6.94%	3.18%	1 797 977 796.00
	H39021099	185 709 649.00	25.8%	4.07%	185 709 649.00	4.3%	0.68%	1880 000 000.00	7.1%	3.25%	313 333 333.33	7.09%	3.25%	1 694 290 351.00
	H39023000	378 940 449.00	52.7%	8.30%	2 273 642 694.00	52.7%	8.30%	6 868 000 000.00	25.9%	11.88%	1 144 666 666.67	25.91%	11.88%	6 489 059 551.00
	H39029000	74 411 476.67	10.3%	1.63%	446 468 860.00	10.3%	1.63%	108 345 161.00	0.4%	0.19%	18 057 526.83	0.41%	0.19%	33 933 684.33
Total value (ZAR)		719 015 709.67	100%	16%	4 314 094 258.00	100.0%	15.74%	################	100.00%	45.86%	4 418 379 555.33	100.00%	45.86%	25 791 261 622.33

Figure D.6: PP data obtained from Quantec (2016) for calculations for different PE types between 2010 and 2015.

D.6 Upstream PP input/output: South Africa

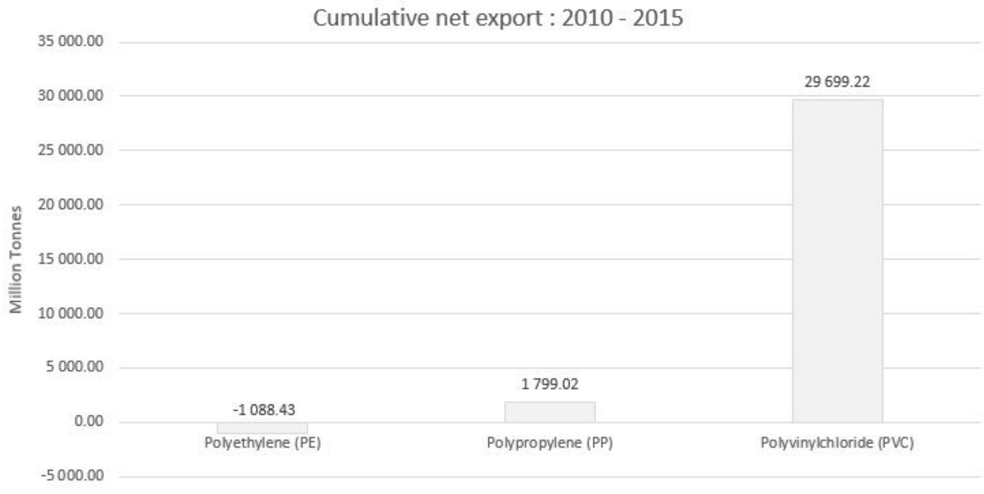
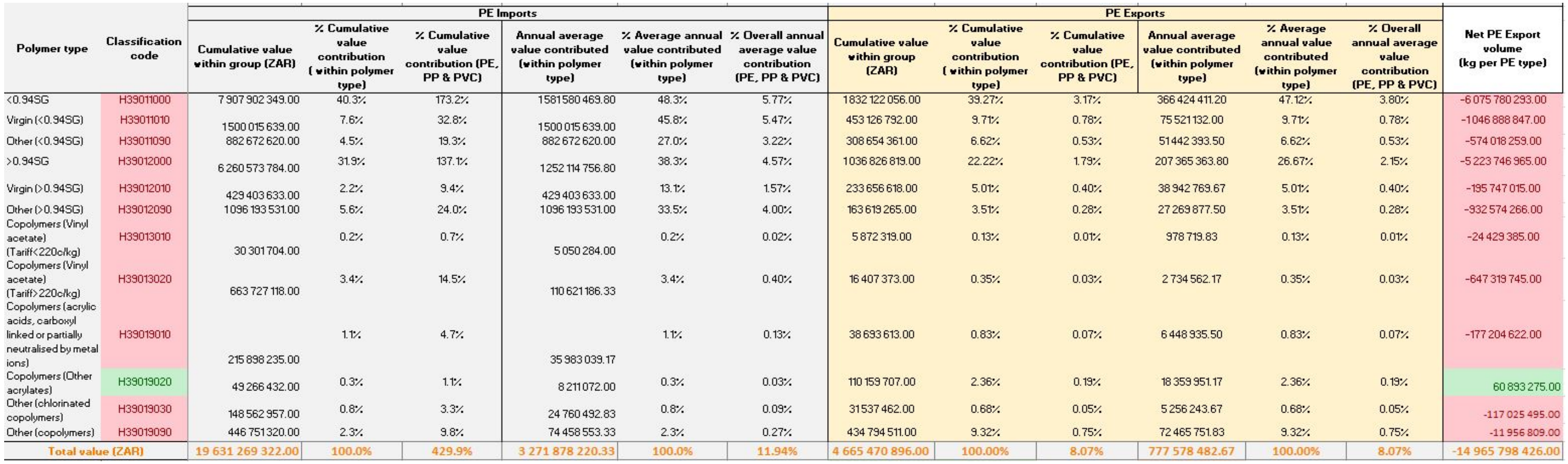


Figure D.7: Cumulative net polyethylene export between 2010 and 2015. Data source : Quantec (2016).



Polymer type	Classification code	PE Imports						PE Exports						Net PE Export volume (kg per PE type)
		Cumulative value within group (ZAR)	% Cumulative value contribution (within polymer type)	% Cumulative value contribution (PE, PP & PVC)	Annual average value contributed (within polymer type)	% Average annual value contributed (within polymer type)	% Overall annual average value contribution (PE, PP & PVC)	Cumulative value within group (ZAR)	% Cumulative value contribution (within polymer type)	% Cumulative value contribution (PE, PP & PVC)	Annual average value contributed (within polymer type)	% Average annual value contributed (within polymer type)	% Overall annual average value contribution (PE, PP & PVC)	
<0.94SG	H39011000	7 907 902 349.00	40.3%	173.2%	1581 580 469.80	48.3%	5.77%	1832 122 056.00	39.27%	3.17%	366 424 411.20	47.12%	3.80%	-6 075 780 293.00
Virgin (<0.94SG)	H39011010	1500 015 639.00	7.6%	32.8%	1500 015 639.00	45.8%	5.47%	453 126 792.00	9.71%	0.78%	75 521 132.00	9.71%	0.78%	-1046 888 847.00
Other (<0.94SG)	H39011090	882 672 620.00	4.5%	19.3%	882 672 620.00	27.0%	3.22%	308 654 361.00	6.62%	0.53%	51 442 393.50	6.62%	0.53%	-574 018 259.00
>0.94SG	H39012000	6 260 573 784.00	31.9%	137.1%	1252 114 756.80	38.3%	4.57%	1036 826 819.00	22.22%	1.79%	207 365 363.80	26.67%	2.15%	-5 223 746 965.00
Virgin (>0.94SG)	H39012010	429 403 633.00	2.2%	9.4%	429 403 633.00	13.1%	1.57%	233 656 618.00	5.01%	0.40%	38 942 769.67	5.01%	0.40%	-195 747 015.00
Other (>0.94SG)	H39012090	1096 193 531.00	5.6%	24.0%	1096 193 531.00	33.5%	4.00%	163 619 265.00	3.51%	0.28%	27 269 877.50	3.51%	0.28%	-932 574 266.00
Copolymers (Vinyl acetate) (Tariff<220c/kg)	H39013010	30 301 704.00	0.2%	0.7%	5 050 284.00	0.2%	0.02%	5 872 319.00	0.13%	0.01%	978 719.83	0.13%	0.01%	-24 429 385.00
Copolymers (Vinyl acetate) (Tariff>220c/kg)	H39013020	663 727 118.00	3.4%	14.5%	110 621 186.33	3.4%	0.40%	16 407 373.00	0.35%	0.03%	2 734 562.17	0.35%	0.03%	-647 319 745.00
Copolymers (acrylic acids, carboxyl linked or partially neutralised by metal ions)	H39019010	215 898 235.00	1.1%	4.7%	35 983 039.17	1.1%	0.13%	38 693 613.00	0.83%	0.07%	6 448 935.50	0.83%	0.07%	-177 204 622.00
Copolymers (Other acrylates)	H39019020	49 266 432.00	0.3%	1.1%	8 211 072.00	0.3%	0.03%	110 159 707.00	2.36%	0.19%	18 359 951.17	2.36%	0.19%	60 893 275.00
Other (chlorinated copolymers)	H39019030	148 562 957.00	0.8%	3.3%	24 760 492.83	0.8%	0.09%	31537 462.00	0.68%	0.05%	5 256 243.67	0.68%	0.05%	-117 025 495.00
Other (copolymers)	H39019090	446 751 320.00	2.3%	9.8%	74 458 553.33	2.3%	0.27%	434 794 511.00	9.32%	0.75%	72 465 751.83	9.32%	0.75%	-11 956 809.00
Total value (ZAR)		19 631 269 322.00	100.0%	429.9%	3 271 878 220.33	100.0%	11.94%	4 665 470 896.00	100.00%	8.07%	777 578 482.67	100.00%	8.07%	-14 965 798 426.00

Figure D.8: PE rand values used for calculations for different PE types between 2010 and 2015. Data source: Quantec (2016).

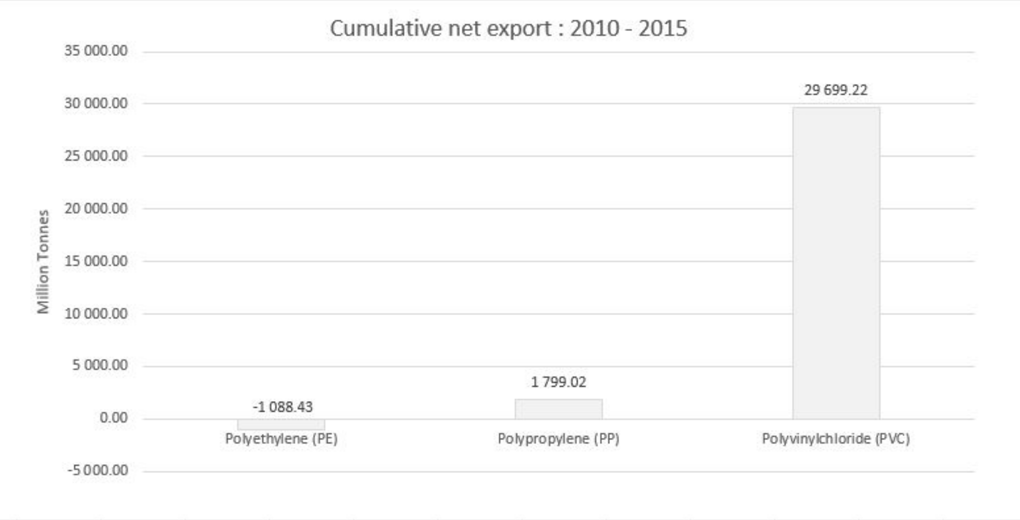


Figure D.9: Cumulative net polyethylene export between 2010 and 2015. Data source: Quantec (2016).

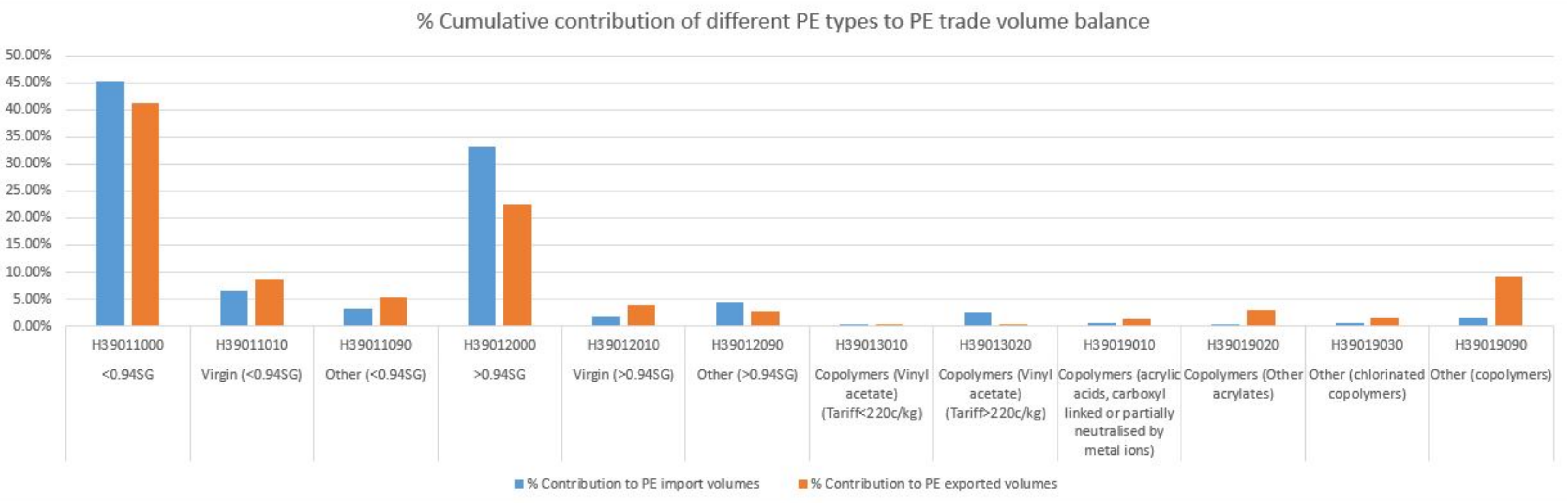


Figure D.10: Percentage contribution of different PE types to the cumulative traded volumes for polyethylene between 2010 and 2015. Data source: Quantec (2016).

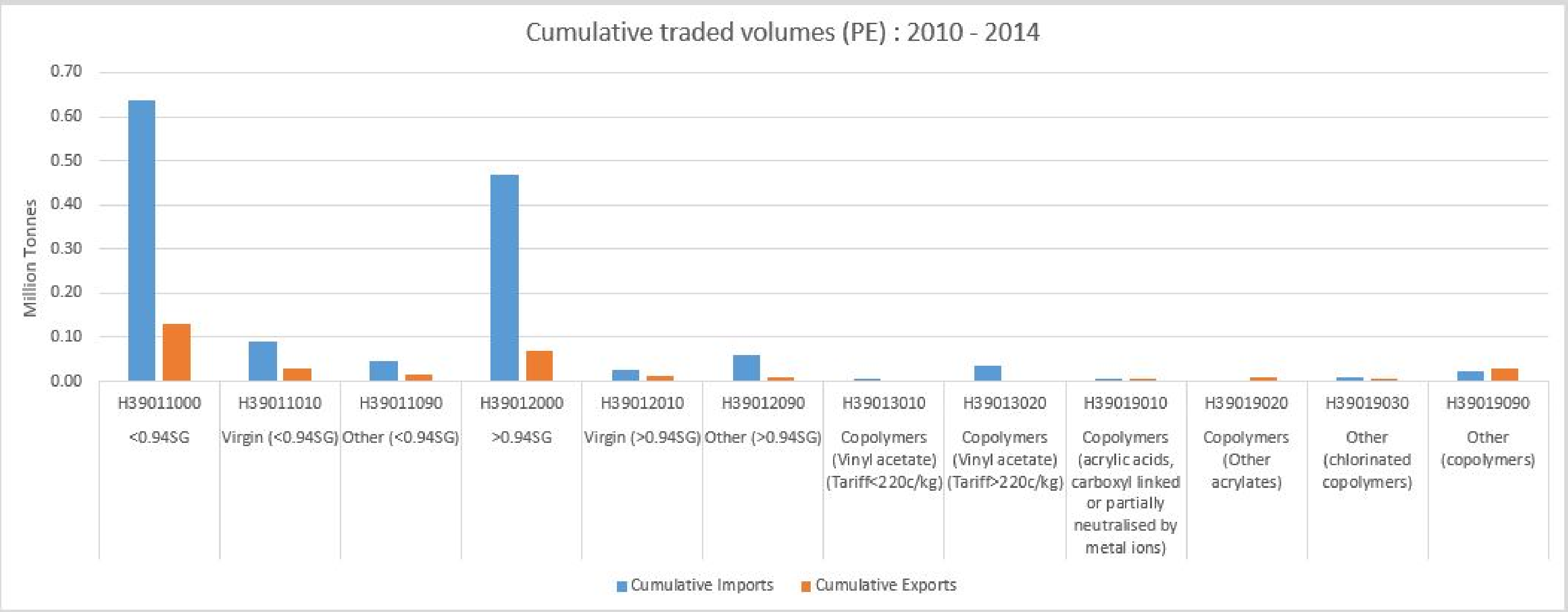


Figure D.11: Volume contribution of different PE types to the cumulative traded volumes for polyethylene between 2010 and 2015. Data source: Quantec (2016).

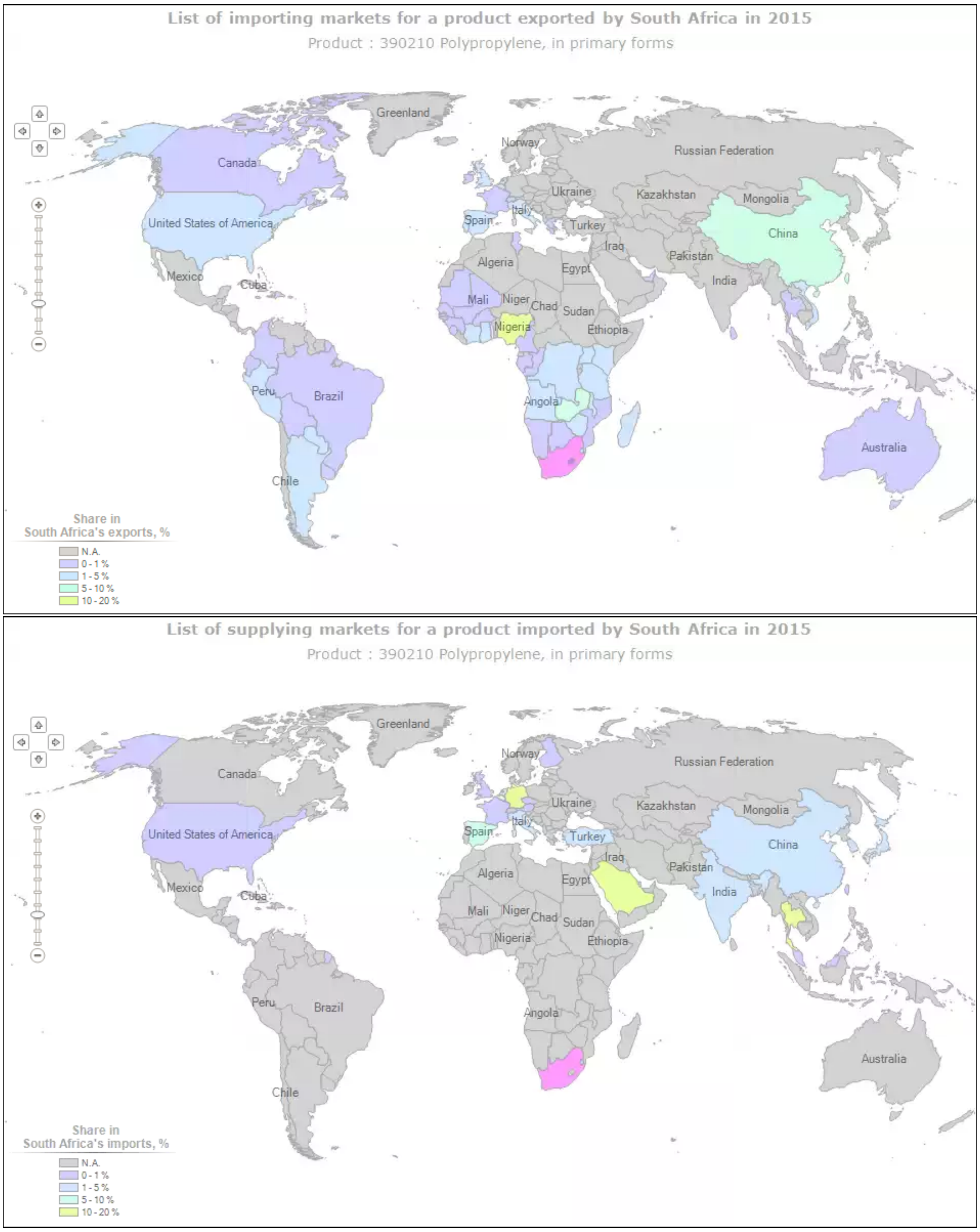


Figure D.12: An illustration of major PP import origin and export destinations for South Africa. Data source: Trademap.

Appendix E

GVC analysis approach

Fig E.1 shows the proposed result template for scenario analysis of demand elasticity as driver for volume, supply and price decisions along polymer value chain.

sample.png

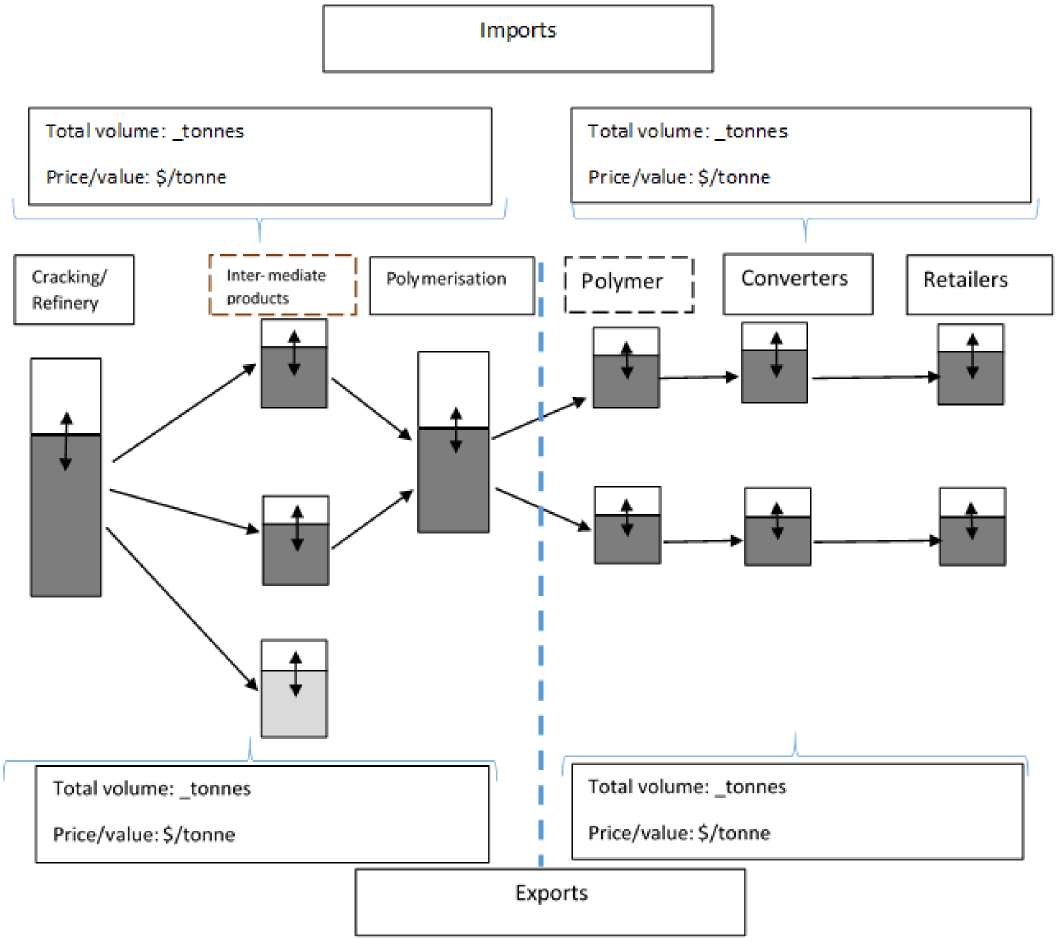
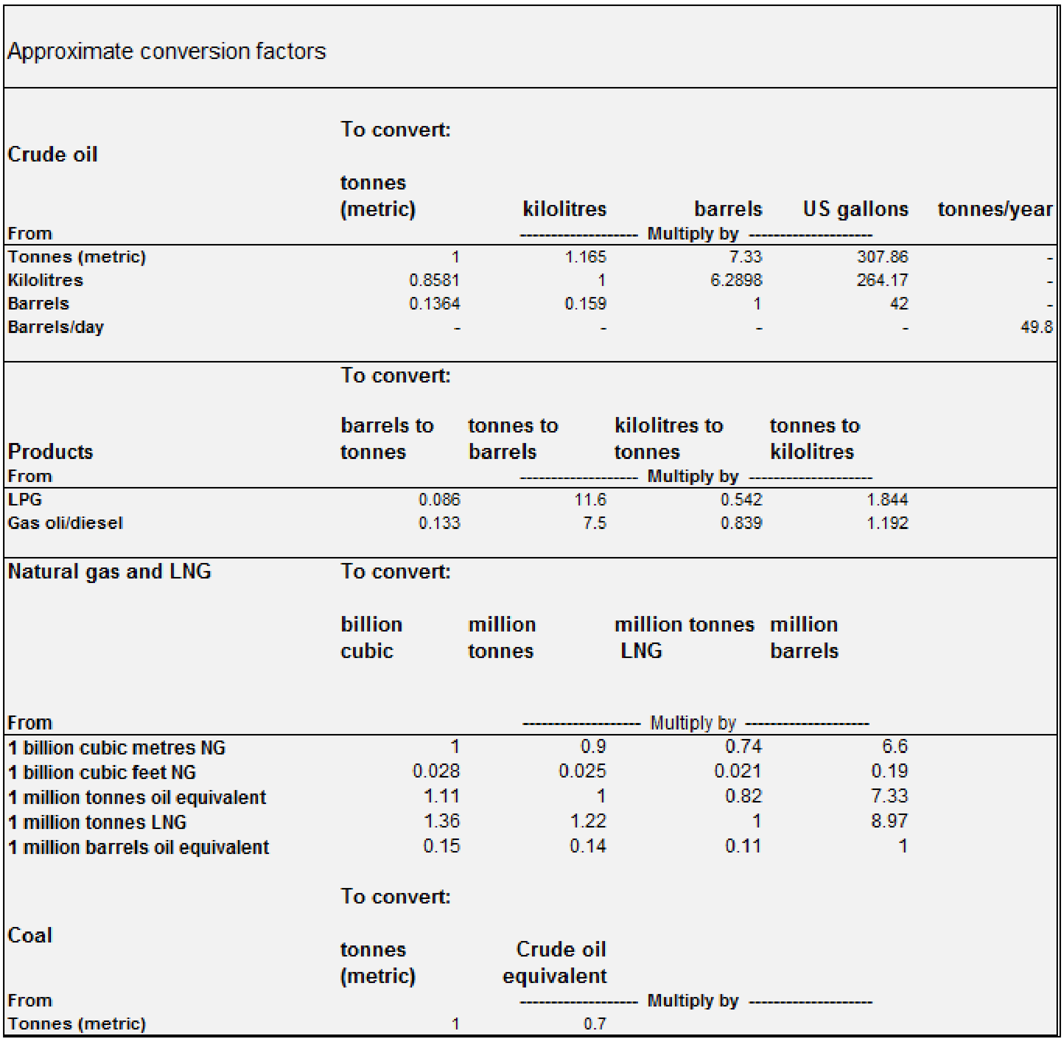


Figure E.1: GVC approach to demand elasticity as driver for volume, supply and price decisions along polypropylene value chain



Approximate conversion factors

Crude oil	To convert:				
	tonnes (metric)	kilolitres	barrels	US gallons	tonnes/year
From		------------------ Multiply by ------------------			
Tonnes (metric)	1	1.165	7.33	307.86	-
Kilolitres	0.8581	1	6.2898	264.17	-
Barrels	0.1364	0.159	1	42	-
Barrels/day	-	-	-	-	49.8

Products	To convert:			
	barrels to tonnes	tonnes to barrels	kilolitres to tonnes	tonnes to kilolitres
From		------------------ Multiply by ------------------		
LPG	0.086	11.6	0.542	1.844
Gas oil/diesel	0.133	7.5	0.839	1.192

Natural gas and LNG	To convert:			
	billion cubic	million tonnes	million tonnes LNG	million barrels
From		------------------ Multiply by ------------------		
1 billion cubic metres NG	1	0.9	0.74	6.6
1 billion cubic feet NG	0.028	0.025	0.021	0.19
1 million tonnes oil equivalent	1.11	1	0.82	7.33
1 million tonnes LNG	1.36	1.22	1	8.97
1 million barrels oil equivalent	0.15	0.14	0.11	1

Coal	To convert:	
	tonnes (metric)	Crude oil equivalent
From		------------------ Multiply by ------------------
Tonnes (metric)	1	0.7

Figure E.2: GVC approach to demand elasticity as driver for volume, supply and price decisions along polypropylene value chain

Appendix F

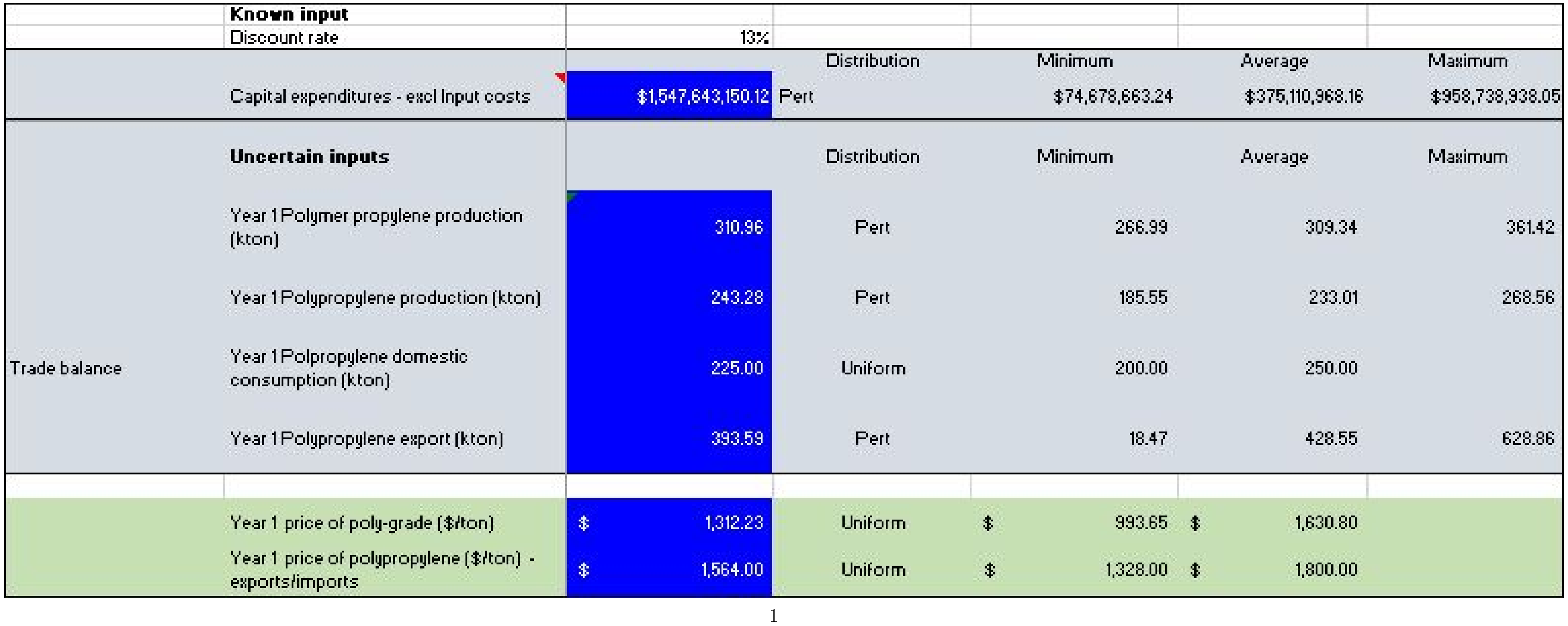
NPV Simulation and scenario analysis

F.1 Supplementary: NPV Modelling

Production and product price inputs for the NPV model, their respective correlations, probability distributions and distribution limits are briefly discussed in this section. Thereafter, an overview of formulas for the NPV model outputs is briefly illustrated.

F.1.1 Model inputs and risk distribution

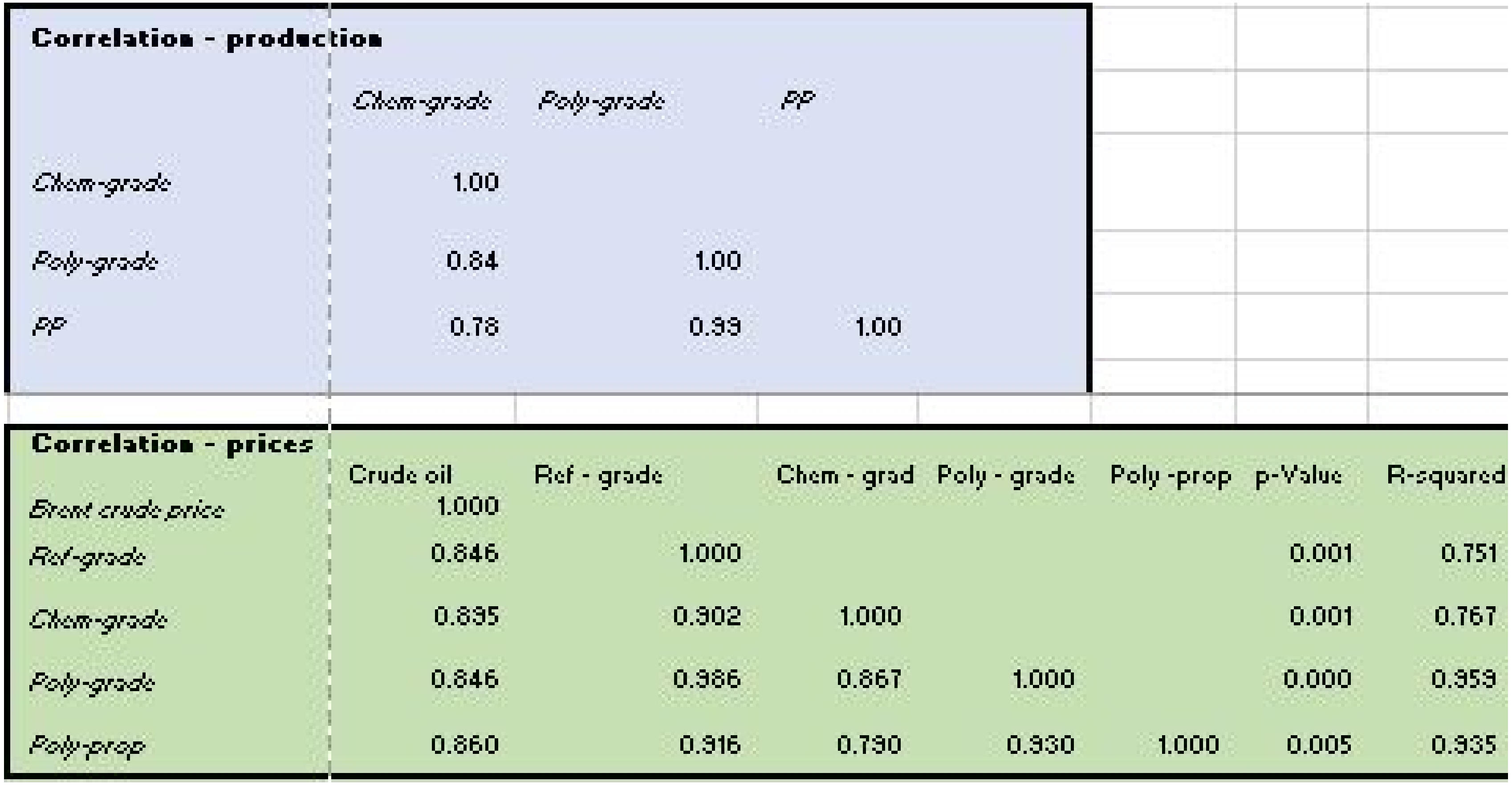
An illustration of the inputs including risk distributions encompassing the levels of uncertainty for the model are shown in Fig F.1, while the associated correlations for production activities and product prices are shown in Fig F.2.



	Known input					
	Discount rate	13%				
			Distribution	Minimum	Average	Maximum
	Capital expenditures - excl Input costs	$1,547,643,150.12	Pert	$74,678,663.24	$375,110,968.16	$958,738,938.05
	Uncertain inputs		Distribution	Minimum	Average	Maximum
	Year 1 Polymer propylene production (kton)	310.96	Pert	266.99	309.34	361.42
	Year 1 Polypropylene production (kton)	243.28	Pert	185.55	233.01	268.56
Trade balance	Year 1 Polpropylene domestic consumption (kton)	225.00	Uniform	200.00	250.00	
	Year 1 Polypropylene export (kton)	393.59	Pert	18.47	428.55	628.86
	Year 1 price of poly-grade ($/ton)	$ 1,312.23	Uniform	$ 993.65	$ 1,630.80	
	Year 1 price of polypropylene ($/ton) - exports/imports	$ 1,564.00	Uniform	$ 1,328.00	$ 1,800.00	

1

Figure F.1: Illustration of @Risk inputs for the NPV model.



Correlation - production

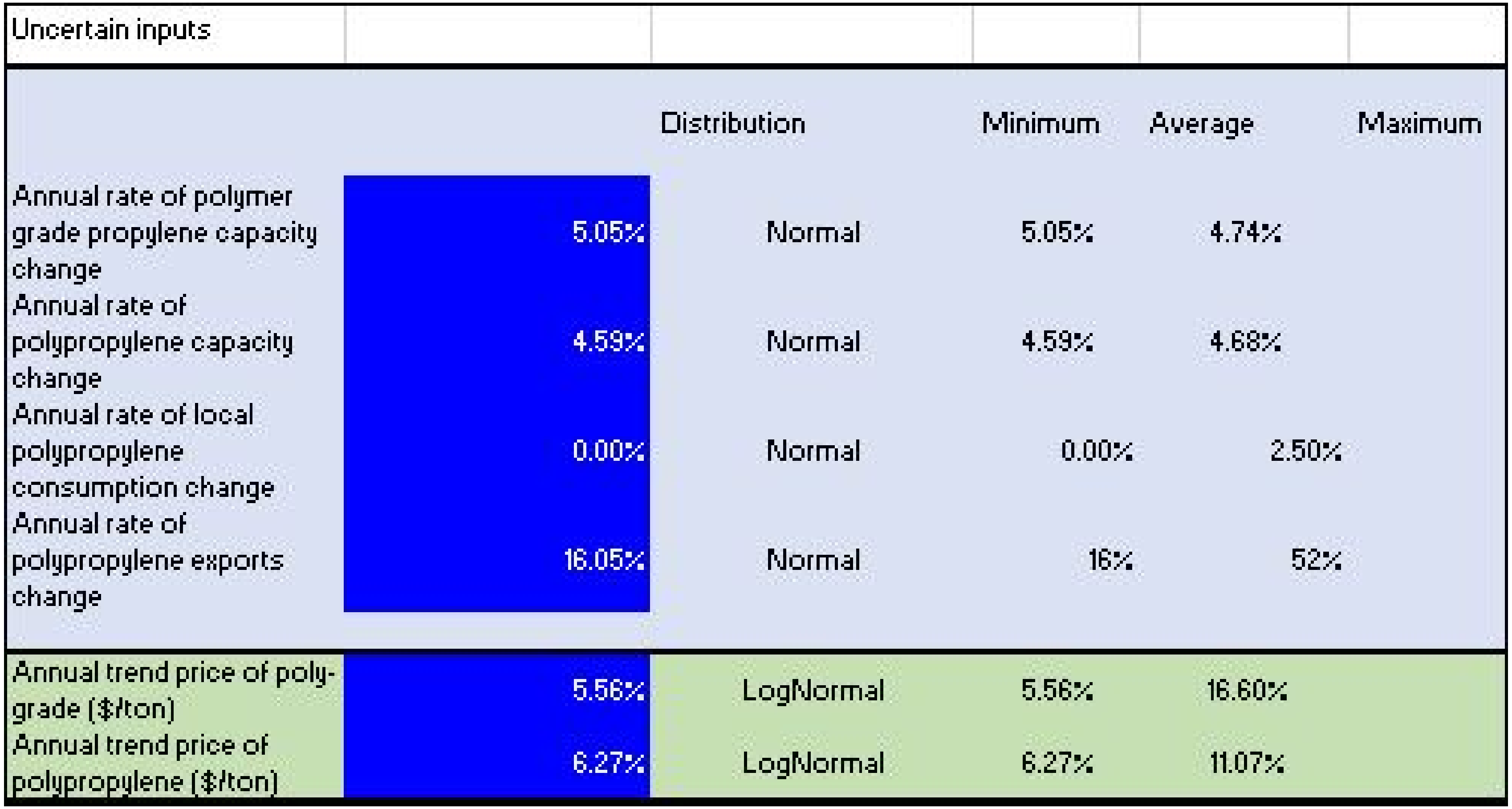
	Chem-grade	*Poly-grade*	*PP*
Chem-grade	1.00		
Poly-grade	0.84	1.00	
PP	0.78	0.99	1.00

Correlation - prices

	Crude oil	Ref - grade	Chem - grad	Poly - grade	Poly -prop	p-Value	R-squared
Brent crude price	1.000						
Ref-grade	0.846	1.000				0.001	0.751
Chem-grade	0.895	0.902	1.000			0.001	0.767
Poly-grade	0.846	0.986	0.867	1.000		0.000	0.959
Poly-prop	0.860	0.916	0.790	0.930	1.000	0.005	0.935

Figure F.2: Correlations associated with the @Risk model inputs for the NPV analysis.

In order to estimate future production and product prices, factoring in risk uncertainties and relative historical performance, trends in production and price were also modelled with risk distributions to allow more realistic fluctuations in these inputs as shown in Fig F.3. Trade balance inputs for imports and exports could not be modeled since the export values are surplus dependent on domestic consumption, while imports are unrelated to domestic consumption. Imports were found to be unrelated to local production in Section 6.5 due to polypropylene converters seeking polypropylene grades not produced locally.

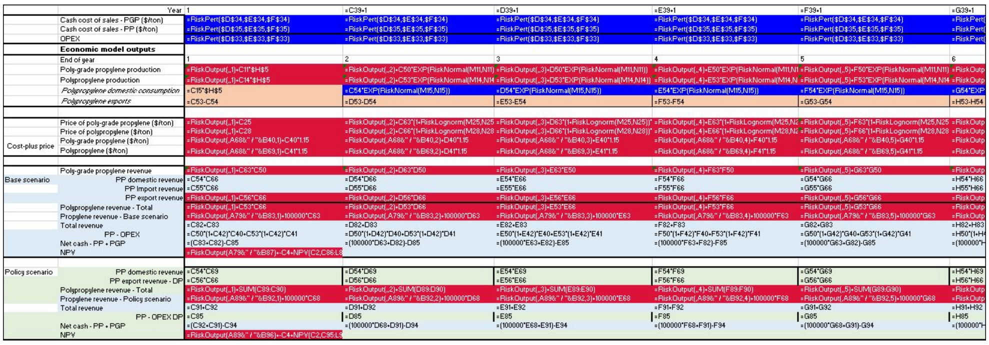


Uncertain inputs					
		Distribution	Minimum	Average	Maximum
Annual rate of polymer grade propylene capacity change	5.05%	Normal	5.05%	4.74%	
Annual rate of polypropylene capacity change	4.59%	Normal	4.59%	4.68%	
Annual rate of local polypropylene consumption change	0.00%	Normal	0.00%	2.50%	
Annual rate of polypropylene exports change	16.05%	Normal	16%	52%	
Annual trend price of poly-grade ($/ton)	5.56%	LogNormal	5.56%	16.60%	
Annual trend price of polypropylene ($/ton)	6.27%	LogNormal	6.27%	11.07%	

Figure F.3: Trends in production and product prices for the NPV model.

F.1.2 Model Outputs and NPV Excel formulae

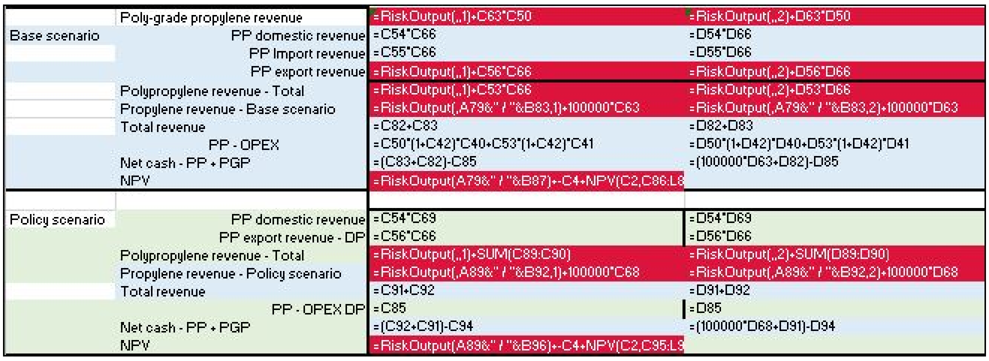
Once the uncertainty in inputs was modelled, the CAPEX, OPEX coefficient, cost of sales per ton (polymer grade propylene and polypropylene), production and product price outpuas well as expected revenues were then calculated as shown in Fig F.4 for each year from year 1 to year 10.



	Year	1	=C39+1	=D39+1	=E39+1	=F39+1	=G39+1
	Cash cost of sales - PGP ($/ton)	=RiskPert(D34,E34,F34)	=RiskPert(D34,E34,F34)	=RiskPert(D34,E34,F34)	=RiskPert(D34,E34,F34)	=RiskPert(D34,E34,F34)	=RiskPert(
	Cash cost of sales - PP ($/ton)	=RiskPert(D35,E35,F35)	=RiskPert(D35,E35,F35)	=RiskPert(D35,E35,F35)	=RiskPert(D35,E35,F35)	=RiskPert(D35,E35,F35)	=RiskPert(
	OPEX	=RiskPert(D33,E33,F33)	=RiskPert(D33,E33,F33)	=RiskPert(D33,E33,F33)	=RiskPert(D33,E33,F33)	=RiskPert(D33,E33,F33)	=RiskPert(
	Economic model outputs						
	End of year	1	2	3	4	5	6
	Poly-grade propylene production	=RiskOutput(,,1)+C11*H5	=RiskOutput(,,2)+C50*EXP(RiskNormal(M11,N11)	=RiskOutput(,,3)+D50*EXP(RiskNormal(M11,N11))	=RiskOutput(,,4)+E50*EXP(RiskNormal(M11,N1	=RiskOutput(,,5)+F50*EXP(RiskNormal(M11,N11)	=RiskOutp
	Polypropylene production	=RiskOutput(,,1)+C14*H5	=RiskOutput(,,2)+C53*EXP(RiskNormal(M14,N14	=RiskOutput(,,3)+D53*EXP(RiskNormal(M14,N14))	=RiskOutput(,,4)+E53*EXP(RiskNormal(M14,N	=RiskOutput(,,5)+F53*EXP(RiskNormal(M14,N14	=RiskOutp
	Polypropylene domestic consumption	=C15*H5	=C54*EXP(RiskNormal(M15,N15))	=D54*EXP(RiskNormal(M15,N15))	=E54*EXP(RiskNormal(M15,N15))	=F54*EXP(RiskNormal(M15,N15))	=G54*EXP
	Polypropylene exports	=C53-C54	=D53-D54	=E53-E54	=F53-F54	=G53-G54	=H53-H54
	Price of poly-grade propylene ($/ton)	=RiskOutput(,,1)+C25	=RiskOutput(,,2)+C63*(1+RiskLognorm(M25,N25	=RiskOutput(,,3)+D63*(1+RiskLognorm(M25,N25))*	=RiskOutput(,,4)+E63*(1+RiskLognorm(M25,N2	=RiskOutput(,,5)+F63*(1+RiskLognorm(M25,N25	=RiskOutp
	Price of polypropylene ($/ton)	=RiskOutput(,,1)+C28	=RiskOutput(,,2)+C66*(1+RiskLognorm(M28,N28	=RiskOutput(,,3)+D66*(1+RiskLognorm(M28,N28))*	=RiskOutput(,,4)+E66*(1+RiskLognorm(M28,N2	=RiskOutput(,,5)+F66*(1+RiskLognorm(M28,N28	=RiskOutp
Cost-plus price	Poly-grade propylene ($/ton)	=RiskOutput(,A68&" / "&B40,1)+C40*1.15	=RiskOutput(,A68&" / "&B40,2)+D40*1.15	=RiskOutput(,A68&" / "&B40,3)+E40*1.15	=RiskOutput(,A68&" / "&B40,4)+F40*1.15	=RiskOutput(,A68&" / "&B40,5)+G40*1.15	=RiskOutp
	Polypropylene ($/ton)	=RiskOutput(,A68&" / "&B69,1)+C41*1.15	=RiskOutput(,A68&" / "&B69,2)+D41*1.15	=RiskOutput(,A68&" / "&B69,3)+E41*1.15	=RiskOutput(,A68&" / "&B69,4)+F41*1.15	=RiskOutput(,A68&" / "&B69,5)+G41*1.15	=RiskOutp
	Poly-grade propylene revenue	=RiskOutput(,,1)+C63*C50	=RiskOutput(,,2)+D63*D50	=RiskOutput(,,3)+E63*E50	=RiskOutput(,,4)+F63*F50	=RiskOutput(,,5)+G63*G50	=RiskOutp
Base scenario	PP domestic revenue	=C54*C66	=D54*D66	=E54*E66	=F54*F66	=G54*G66	=H54*H66
	PP Import revenue	=C55*C66	=D55*D66	=E55*E66	=F55*F66	=G55*G66	=H55*H66
	PP export revenue	=RiskOutput(,,1)+C56*C66	=RiskOutput(,,2)+D56*D66	=RiskOutput(,,3)+E56*E66	=RiskOutput(,,4)+F56*F66	=RiskOutput(,,5)+G56*G66	=RiskOutp
	Polypropylene revenue - Total	=RiskOutput(,,1)+C53*C66	=RiskOutput(,,2)+D53*D66	=RiskOutput(,,3)+E53*E66	=RiskOutput(,,4)+F53*F66	=RiskOutput(,,5)+G53*G66	=RiskOutp
	Propylene revenue - Base scenario	=RiskOutput(,A79&" / "&B83,1)+100000*C63	=RiskOutput(,A79&" / "&B83,2)+100000*D63	=RiskOutput(,A79&" / "&B83,3)+100000*E63	=RiskOutput(,A79&" / "&B83,4)+100000*F63	=RiskOutput(,A79&" / "&B83,5)+100000*G63	=RiskOutp
	Total revenue	=C82+C83	=D82+D83	=E82+E83	=F82+F83	=G82+G83	=H82+H83
	PP - OPEX	=C50*(1+C42)*C40+C53*(1+C42)*C41	=D50*(1+D42)*D40+D53*(1+D42)*D41	=E50*(1+E42)*E40+E53*(1+E42)*E41	=F50*(1+F42)*F40+F53*(1+F42)*F41	=G50*(1+G42)*G40+G53*(1+G42)*G41	=H50*(1+H4
	Net cash - PP + PGP	=(C83+C82)-C85	=(100000*D63+D82)-D85	=(100000*E63+E82)-E85	=(100000*F63+F82)-F85	=(100000*G63+G82)-G85	=(100000*H
	NPV	=RiskOutput(A79&" / "&B87)+-C4+NPV(C2,C86:L8					
Policy scenario	PP domestic revenue	=C54*C69	=D54*D69	=E54*E69	=F54*F69	=G54*G69	=H54*H69
	PP export revenue - DP	=C56*C66	=D56*D66	=E56*E66	=F56*F66	=G56*G66	=H56*H66
	Polypropylene revenue - Total	=RiskOutput(,,1)+SUM(C89:C90)	=RiskOutput(,,2)+SUM(D89:D90)	=RiskOutput(,,3)+SUM(E89:E90)	=RiskOutput(,,4)+SUM(F89:F90)	=RiskOutput(,,5)+SUM(G89:G90)	=RiskOutp
	Propylene revenue - Policy scenario	=RiskOutput(,A89&" / "&B92,1)+100000*C68	=RiskOutput(,A89&" / "&B92,2)+100000*D68	=RiskOutput(,A89&" / "&B92,3)+100000*E68	=RiskOutput(,A89&" / "&B92,4)+100000*F68	=RiskOutput(,A89&" / "&B92,5)+100000*G68	=RiskOutp
	Total revenue	=C91+C92	=D91+D92	=E91+E92	=F91+F92	=G91+G92	=H91+H92
	PP - OPEX DP	=C85	=D85	=E85	=F85	=G85	=H85
	Net cash - PP + PGP	=(C92+C91)-C94	=(100000*D68+D91)-D94	=(100000*E68+E91)-E94	=(100000*F68+F91)-F94	=(100000*G68+G91)-G94	=(100000*H
	NPV	=RiskOutput(A89&" / "&B96)+-C4+NPV(C2,C95:L9					

Figure F.4: Model outputs for production, product prices and expected revenues for each product.

Base scenario and cost-plus pricing cost-plus (15%) policy scenario NPV calculations were performed according to cashflows for year 1 to 10 as shown in Fig F.5.



	Poly-grade propylene revenue	=RiskOutput(,,1)+C63*C50	=RiskOutput(,,2)+D63*D50
Base scenario	PP domestic revenue	=C54*C66	=D54*D66
	PP Import revenue	=C55*C66	=D55*D66
	PP export revenue	=RiskOutput(,,1)+C56*C66	=RiskOutput(,,2)+D56*D66
	Polypropylene revenue - Total	=RiskOutput(,,1)+C53*C66	=RiskOutput(,,2)+D53*D66
	Propylene revenue - Base scenario	=RiskOutput(,A79&" / "&B83,1)+100000*C63	=RiskOutput(,A79&" / "&B83,2)+100000*D63
	Total revenue	=C82+C83	=D82+D83
	PP - OPEX	=C50*(1+C42)*C40+C53*(1+C42)*C41	=D50*(1+D42)*D40+D53*(1+D42)*D41
	Net cash - PP + PGP	=(C83+C82)-C85	=(100000*D63+D82)-D85
	NPV	=RiskOutput(A79&" / "&B87)+-C4+NPV(C2,C86:L8	
Policy scenario	PP domestic revenue	=C54*C69	=D54*D69
	PP export revenue - DP	=C56*C66	=D56*D66
	Polypropylene revenue - Total	=RiskOutput(,,1)+SUM(C89:C90)	=RiskOutput(,,2)+SUM(D89:D90)
	Propylene revenue - Policy scenario	=RiskOutput(,A89&" / "&B92,1)+100000*C68	=RiskOutput(,A89&" / "&B92,2)+100000*D68
	Total revenue	=C91+C92	=D91+D92
	PP - OPEX DP	=C85	=D85
	Net cash - PP + PGP	=(C92+C91)-C94	=(100000*D68+D91)-D94
	NPV	=RiskOutput(A89&" / "&B96)+-C4+NPV(C2,C95:L9	

Figure F.5: Free cash flow calculations for years 1 to 10 and NPV determination.

F.2 NPV analysis

F.2.1 Base scenario

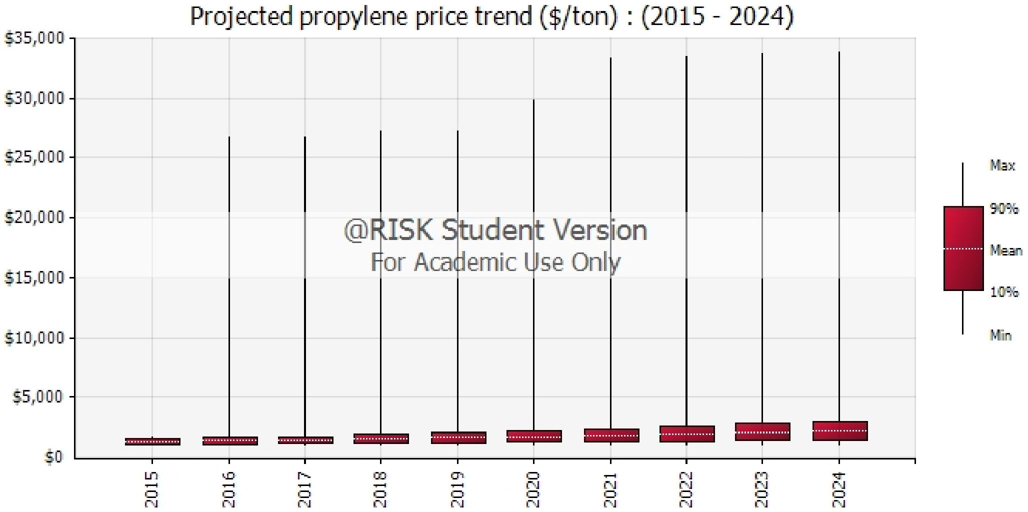


Figure F.6: Price trend for propylene over the 10 year period

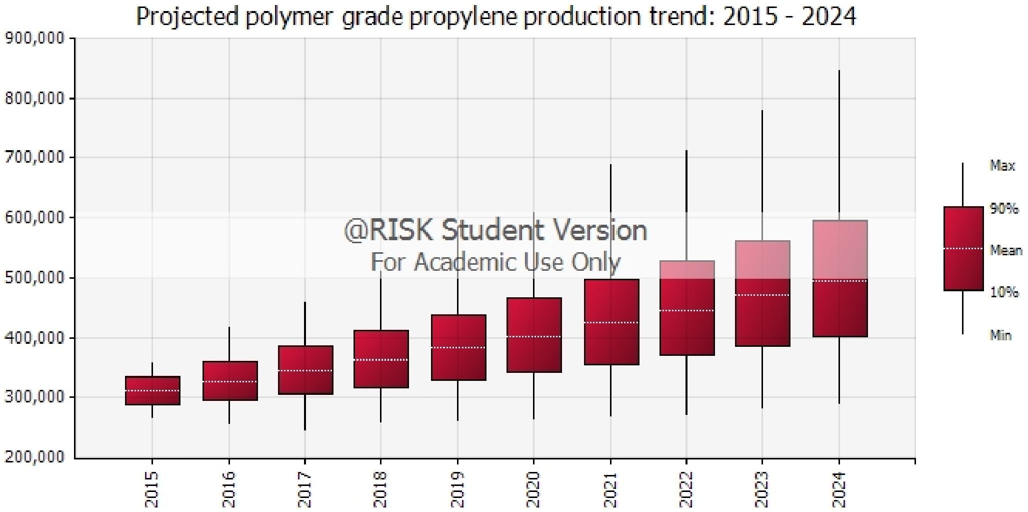


Figure F.7: Production trend for propylene over the 10 year period

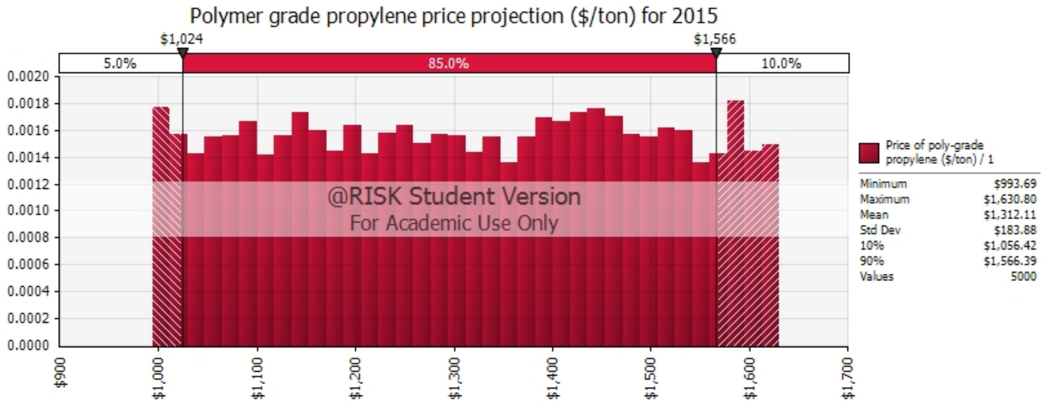

Polymer grade propylene price projection ($/ton) for 2015

Figure F.8: Price projection for propylene for year 1

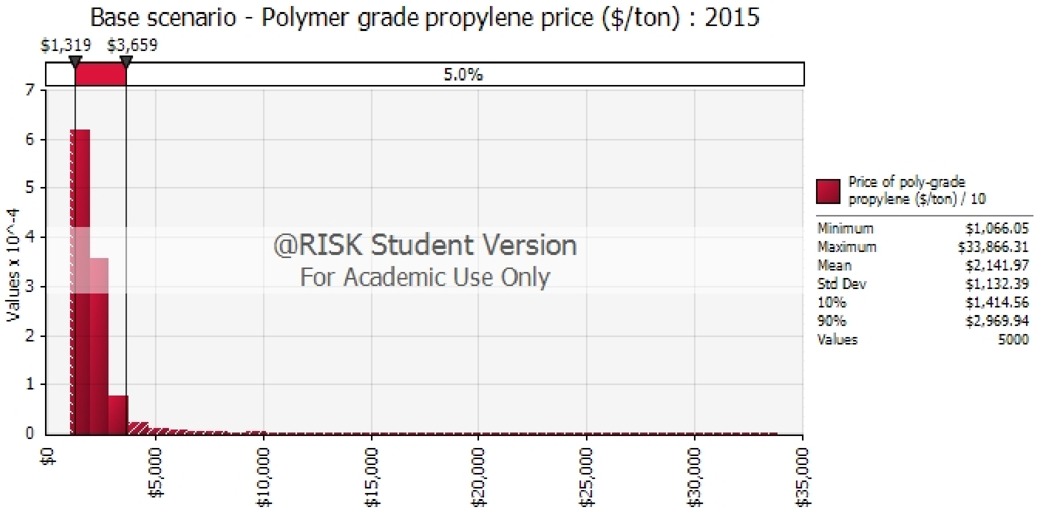

Base scenario - Polymer grade propylene price ($/ton) : 2015

Figure F.9: Price projection for propylene for year 10

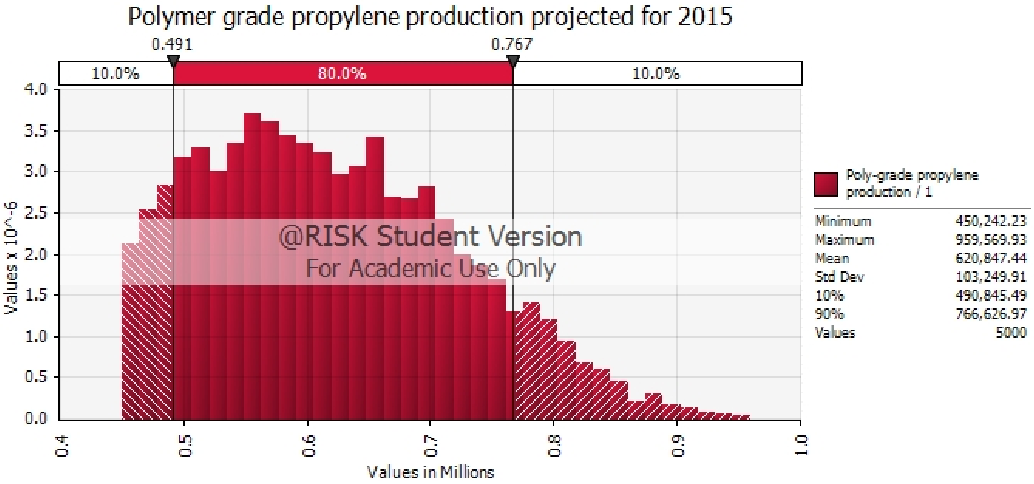


Figure F.10: Production projection for propylene for year 1

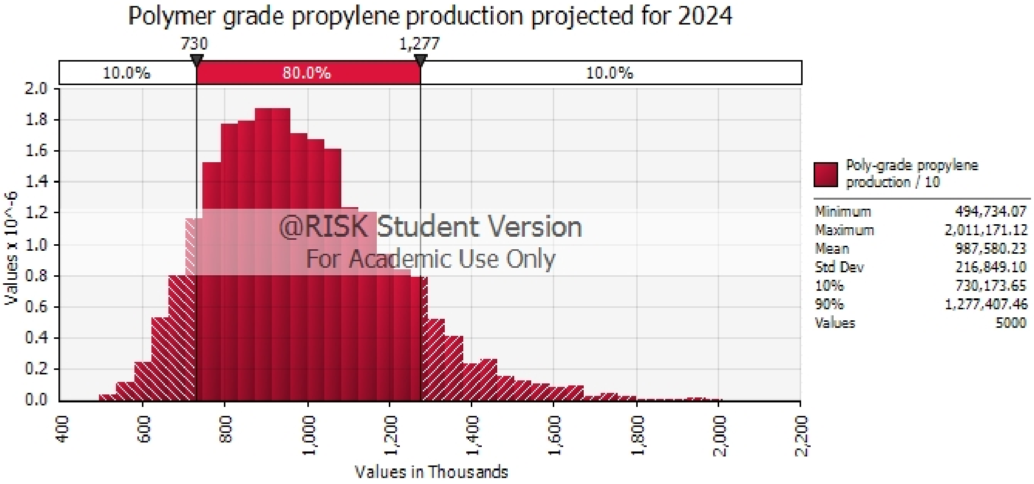


Figure F.11: Production projection for propylene for year 10

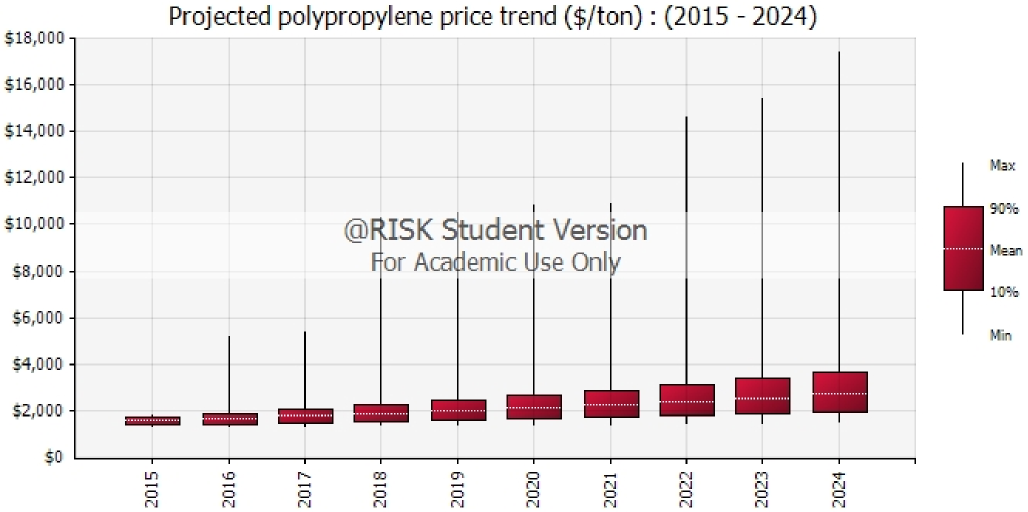


Figure F.12: Price trend for polypropylene over the 10 year period

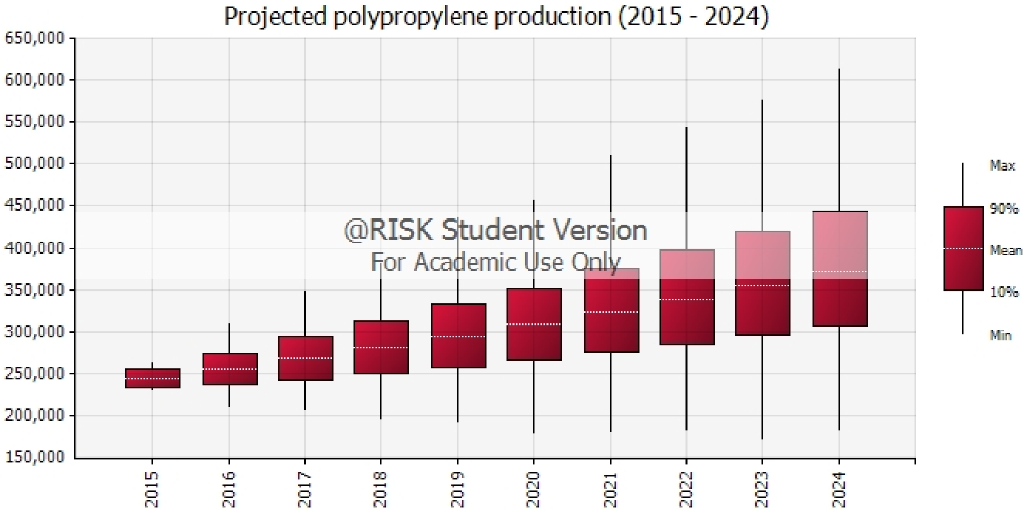


Figure F.13: Production trend for polypropylene over the 10 year period

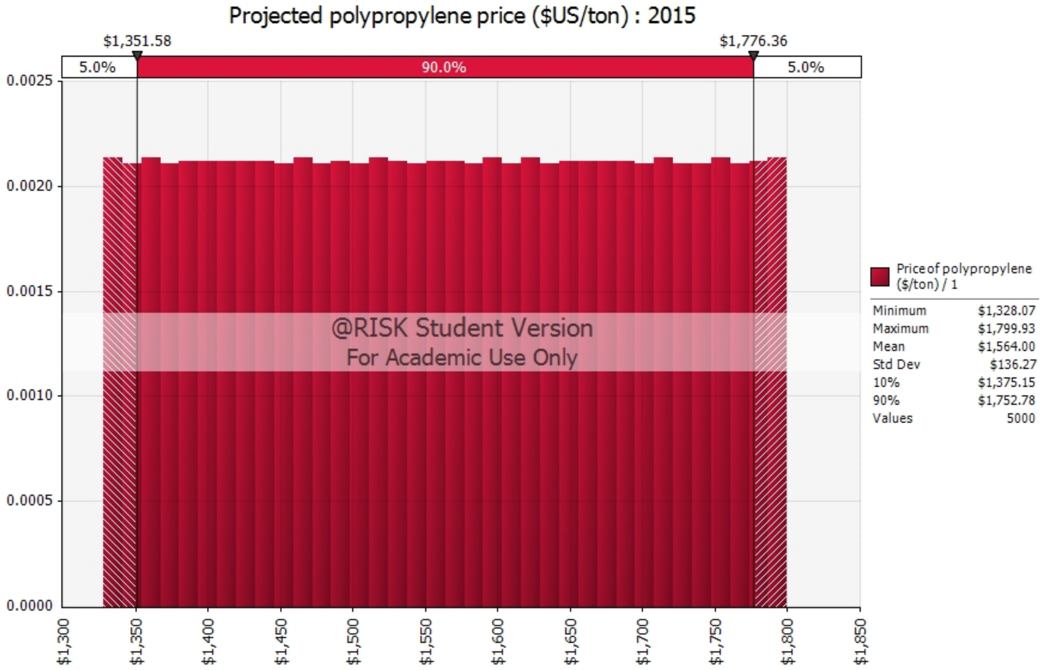


Figure F.14: Price projection for polypropylene for year 1

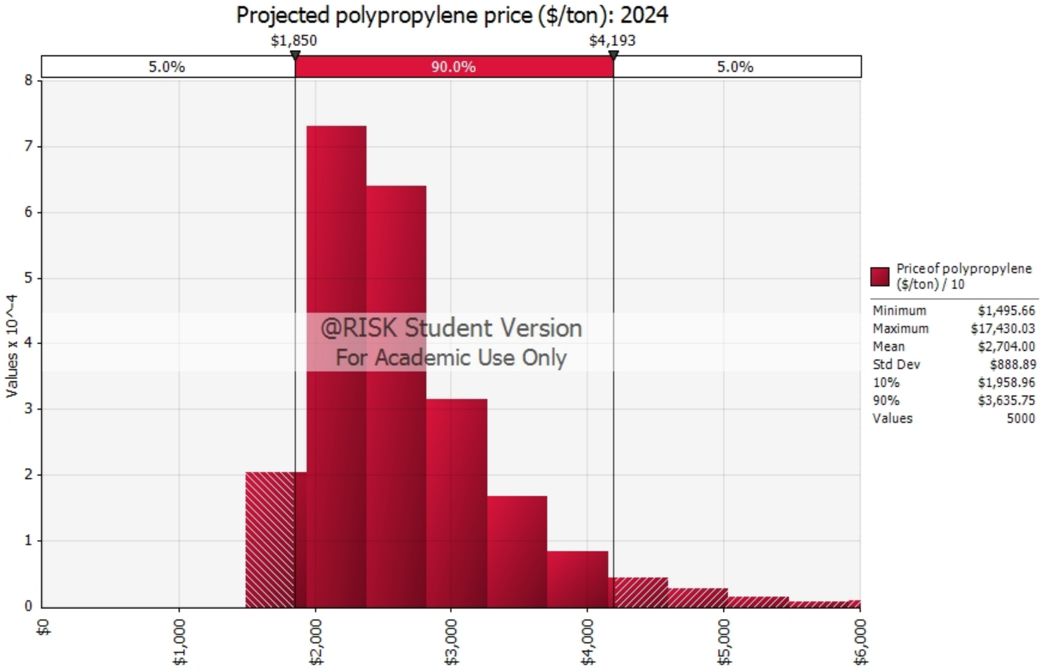


Figure F.15: Price projection for propylene for year 10

		Year	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Base and policy scenario		Discount rate	12.5%									
	Capital expenditures		$1,547,643,150	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Production volumes (tons)	Polymer grade propylene	310,962	327,069	344,010	361,828	380,570	400,282	421,015	442,823	465,760	489,884
		Polypropylene	243,275	254,702	266,665	279,190	292,304	306,033	320,407	335,457	351,213	367,709
OPEX/Production ratio			1.15%	1.15%	1.15%	1.15%	1.15%	1.15%	1.15%	1.15%	1.15%	1.15%
Base scenario	Product price (US$/ton)	Polymer grade propylene	$1,312	$1,385	$1,462	$1,543	$1,629	$1,720	$1,816	$1,916	$2,023	$2,136
		Polypropylene	$1,564	$1,662	$1,766	$1,877	$1,995	$2,120	$2,253	$2,394	$2,544	$2,704
	Industry Revenues	Polymer grade propylene	$131,222,500	$138,518,471	$146,220,098	$154,349,935	$162,931,792	$171,990,799	$181,553,488	$191,647,862	$202,303,483	$213,551,557
		Local - PP	$351,900,000	$373,964,130	$397,411,681	$422,329,393	$448,809,446	$476,949,799	$506,854,551	$538,634,331	$572,406,704	$608,296,604
		Exports - PP	$28,582,332	$49,366,109	$73,591,770	$101,715,974	$134,251,138	$171,771,984	$214,922,847	$264,425,819	$321,089,832	$385,820,784
		Total PP	$380,482,332	$423,330,239	$471,003,451	$524,045,368	$583,060,585	$648,721,783	$721,777,398	$803,060,150	$893,496,536	$994,117,388
	Less	OPEX - PP value chain	$562,368,798	$590,111,682	$619,226,457	$649,781,125	$681,847,068	$715,499,212	$750,816,208	$787,880,617	$826,779,102	$867,602,635
		Net cashflow	-$50,663,967	-$28,262,972	-$2,002,908	$28,614,178	$64,145,309	$105,213,371	$152,514,678	$206,827,395	$269,020,917	$340,066,310
		NPV	-$1,165,654,015									

Figure F.16: Summary of *P90* values for the base scenario

F.2.2 Policy scenario

The trend in the range of sampled prices for propylene and polypropylene are shown in Fig F.17 and Fig F.18 respectively. The prices sampled for both propylene and polypropylene were fairly constant.

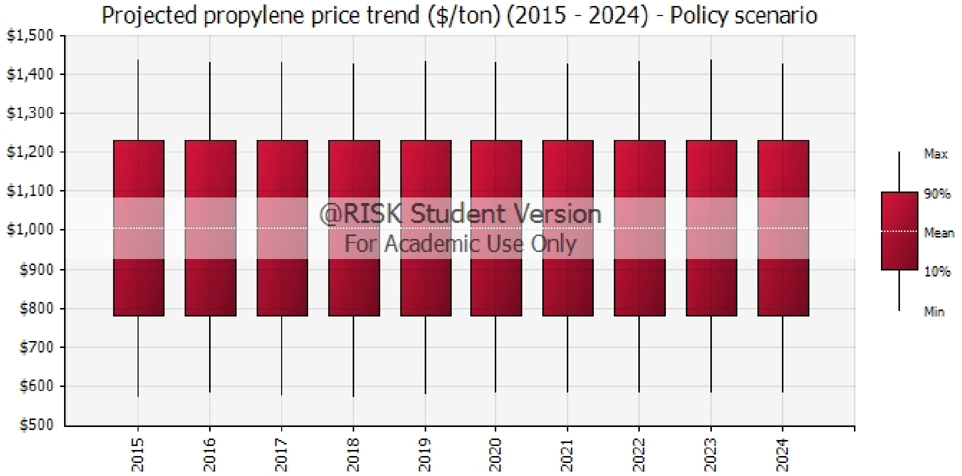


Figure F.17: Price trend for propylene over the 10 year period

Prices sampled for propylene ranged between an average of US$436 and US$440 per tonne annually for the ten year period under study.

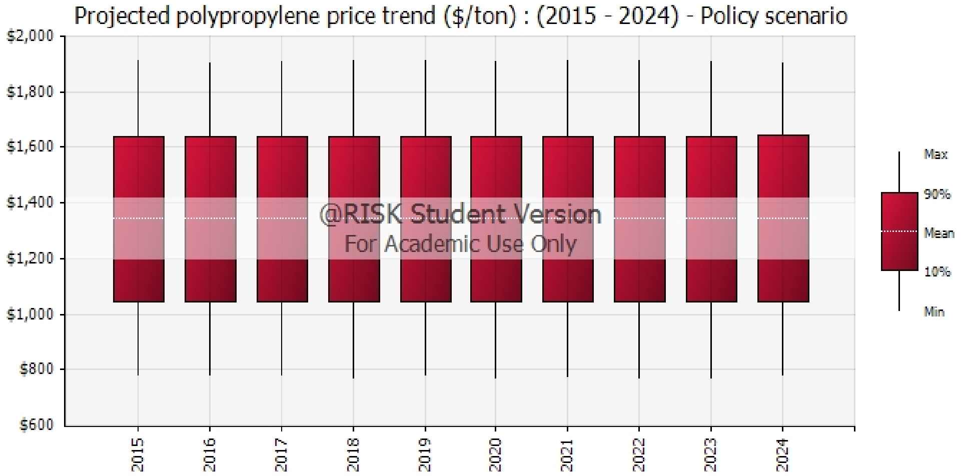


Figure F.18: Price trend for propylene over the 10 year period

Similarly, prices sampled for polypropylene ranged between an average of US$478 and US$480 per tonne annually for the same period. Production volumes sampled in the model for the policy scenario were similar to those used for the base scenario without the policy.

Policy scenario (Cost plus 15%)	Total cost of sales (US$/ton)	Polymer grade propylene	$875	$875	$875	$875	$875	$875	$875	$875	$875	$875
		Polypropylene	$1,167	$1,167	$1,167	$1,167	$1,167	$1,167	$1,167	$1,167	$1,167	$1,167
	Product price (US$/ton)	Polymer grade propylene	$1,006	$1,006	$1,006	$1,006	$1,006	$1,006	$1,006	$1,006	$1,006	$1,006
		Polypropylene	$1,342	$1,342	$1,342	$1,342	$1,342	$1,342	$1,342	$1,342	$1,342	$1,342
	Industry Revenues	Local - PP	$301,918,125	$301,918,125	$301,918,125	$301,918,125	$301,918,125	$301,918,125	$301,918,125	$301,918,125	$301,918,125	$301,918,125
		Exports - PP	$28,582,332	$49,366,109	$73,591,770	$101,715,974	$134,251,138	$171,771,984	$214,922,847	$264,425,819	$321,089,832	$385,820,784
		Total PP	$431,125,457	$451,909,234	$476,134,895	$504,259,099	$536,794,263	$574,315,109	$617,465,972	$666,968,944	$723,632,957	$788,363,909
		Polymer grade propylene	$100,625,000	$100,625,000	$100,625,000	$100,625,000	$100,625,000	$100,625,000	$100,625,000	$100,625,000	$100,625,000	$100,625,000
	Less	OPEX - PP value chain	$562,368,798	$590,111,682	$619,226,457	$649,781,125	$681,847,068	$715,499,212	$750,816,208	$787,880,617	$826,779,102	$867,602,635
		Net cash	-$131,243,342	-$138,202,448	-$143,091,562	-$145,522,026	-$145,052,805	-$141,184,102	-$133,350,236	-$120,911,673	-$103,146,145	-$79,238,725
		NPV	-$2,280,712,119									

Figure F.19: Summary of *P90* values for the policy scenario

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