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Exploring drivers of vertical forward integration in South Africa's platinum mining industry

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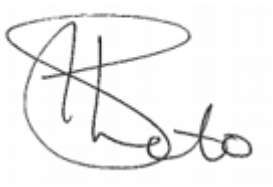
Supervisor Name: Dr Oro Ufuo Oro

Declaration

I, Simon Pheto, declare that this research article is my own work except as indicated in the references and acknowledgements. It is submitted in partial fulfilment of the requirements for the degree of Master of Business Administration in the Graduate School of Business Administration, University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in this or any other university.



Simon Lefika Pheto

Signed at Rustenburg

On the 11th day of May 2023

Dedication

I want to dedicate this study to my family for the unconditional support and the time they gave me to work on this study. Your belief in me and understanding during my absence are genuinely appreciated. Above all, I dedicate this study to All Mighty for the ability to see this research through.

Acknowledgements

To my supervisor, Dr Oro Ufuo Oro, thank you for your guidance and insights to organise the study into a meaningful package. Thanks for your speedy and informative responses every time you reviewed the work.

To the participants who participated in the study, thank you for immersing yourself in the subject and giving us those insightful contributions.

Supplementary Information

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Supplementary files:

1. Ethics Certificate Simon Pheto
2. Top 10 Monthly Commodities raw data
3. Trade data analysis
4. Standard International Trade Classification
5. Research information sheet and consent form
6. Research instrument
7. Participant 1 transcript
8. Participant 2 transcript
9. Participant 4 transcript
10. Code Group Manager

Abstract

Historically, South Africa has positioned itself as a net exporter of refined and semi-finished Platinum Group Metals (PGMs) related products, which has stayed the same. This position generates much-needed foreign capital during commodity booms, but it has a long-lasting catastrophic impact on the economy. As a result, the South African PGMs industry is experiencing the lock-in effect of only specialising in exports of refined and semi-finished PGMs-related products. This trade pattern impairs South Africa's capability to develop a comparative advantage in the export of finished PGMs-related products.

This research seeks to identify, explore, and obtain an in-depth understanding of the drivers of vertical forward integration to migrate the PGMs industry from the export of refined and semi-finished PGMs-related products to finished PGMs-related products. The drivers of vertical forward integration were identified in the literature review. An in-depth understanding of these drivers was obtained through a qualitative research study. The themes associated with these drivers were identified by running structured interviews and analysing the data in Atlas.ti software.

The structured interview results show that export-led industrialisation policies targeting international trade, innovation capabilities, relatedness of capabilities and foreign direct investments (FDI) will transform the South African PGMs industry into a manufacturing sector and exporter of finished PGMs-related products. However, the above drivers of forward vertical integration require a strong and progressive institutional regime with large institutional capital.

The input-output model of the forward vertical integration process in South Africa's PGMs industry takes the PGMs reserves as an input transformed resource and institutional regime as transforming resource. The four remaining drivers, international trade, innovation capabilities, the relatedness of capabilities and FDI are important components in the transforming process. The transforming process entails the creation of new knowledge and new technology, absorption of foreign knowledge and technology, the liberalisation of international trade and entrepreneurship. The output of the above model is finished PGMs-related products.

Key Words

PGMs, forward vertical integration, institutional regime, resources, international trade, innovation capabilities, the relatedness of capabilities, FDI, finished PGMs products.

Contents

Declaration ii

Dedication iii

Acknowledgements iii

Supplementary Information iv

Abstract v

List of Tables ix

List of Figures x

Chapter 1: Introduction 1

1.1 Purpose of the study 1

1.2 Context of the study 1

1.3 Research problem 3

1.4 Research objectives 5

1.5 Research propositions 5

1.6 Significance of the study 5

1.7 Delimitations of the study 6

1.8 Assumptions 6

1.9 Definition of the terms 7

1.10 Conclusion to Chapter 1 7

Chapter 2: Theoretical framework 9

2.1 International Trade Theory 9

2.1.1 Heckscher – Ohlin model 9

2.1.2 The Ricardian model 10

2.1.3 Summary of International Trade Theories 11

2.2 Trade diversification drivers 12

2.2.1 Institutional regime 12

2.2.2 Innovative capabilities 13

2.2.3 Relatedness of capabilities 15

2.2.4 Foreign Direct Investment 16
2.2.5 Summary of trade diversification drivers 17
2.3 Conclusion to Chapter 2 18
Chapter 3: Material and Methods 21
3.1 Study design 21
3.2 Participants' selection and population size 22
3.3 Data collection 23
3.4 Data Analysis 24
3.5 Limitations 27
3.6 Evaluation of the research 27
3.7 Ethics 28
3.8 Conclusion to Chapter 3 29
Chapter 4: Presentation of Findings 31
4.1 Data presentation 31
4.2 International Trade Theory 33
4.2.1 Findings pertaining to Proposition 1a: Large PGMs resources and reserves in South Africa are likely to lock South Africa in export of primary refined PGMs products. 33
4.2.2 Findings pertaining to proposition 1b: Technological know-how will transform South Africa into a net exporter of finished PGMs-related products. 37
4.3 Institutional regime 44
4.3.1 Findings pertaining to Proposition 2: Progressive policies implemented by the formal institutions will cause gradual diversification of South Africa's PGMs industry into a net exporter of finished PGMs-related products. 44
4.3.2 Summary of Proposition 2 findings: Progressive policies implemented by the formal institutions will cause gradual diversification of South Africa's PGMs industry into a net exporter of finished PGMs-related products. 49
4.4 Innovative capabilities 50
4.4.1 Findings pertaining to Proposition 3: Education and innovation strategies in South Africa will likely create diversification of South African PGMs industry. 50
4.4.2 Summary of Proposition 3 findings: Education and innovation strategies in South Africa will likely create diversification of South African PGMs industry. 55
4.5 Relatedness of capabilities 56
4.5.1 Findings pertaining to Proposition 4: South Africa's PGMs product space network density is likely to sustain diversification and expansion of current PGMs-related products. 56

4.5.2 Summary of Proposition 4 findings: South Africa's PGMs product space network density is likely to sustain diversification and expansion of current PGMs-related products. 61
4.6 Foreign Direct Investment 62
4.6.1 Findings pertaining to proposition 5: FDI will likely cause South African PGMs industry to diversify into manufacturing and export of finished PGMs products. 62
4.6.2 Summary of Proposition 5 findings: FDI will likely cause South African PGMs industry to diversify into manufacturing and export of finished PGMs products. 66
4.7 Summary of findings 67
Chapter 5: Discussions of the findings 72
5.1 International Trade Theory 72
5.1.1 Discussions of findings pertaining to Proposition 1a: Large PGMs resources and reserves in South Africa are likely to loc South Africa in export of primary refined PGMs products. 72
5.1.2 Discussions of findings pertaining to Proposition 1b: Technological know-how will transform South Africa into a net exporter of finished PGMs-related products. 73
5.2 Institutional regime 73
5.2.1 Discussions of findings pertaining to Proposition 2: Progressive policies implemented by the formal institutions will cause gradual diversification of South Africa's PGMs industry into a net exporter of finished PGMs-related products. 73
5.3 Innovative capabilities 74
5.3.1 Discussions of findings pertaining to Proposition 3: Education and innovation strategies in South Africa will likely create diversification of South African PGMs industry. 74
5.4 Relatedness of capabilities 75
5.4.1 Discussions of findings pertaining to Proposition 4: South Africa's PGMs product space network density is likely to sustain diversification and expansion of current PGMs-related products. 75
5.5 Foreign Direct Investment 77
5.5.1 Discussion of findings pertaining to proposition 5: FDI will likely cause South African PGMs mining sector to diversify into manufacturing and export of finished PGMs products. 77
5.6 Summary of Discussions 78
Chapter 6: Conclusions 82
6.1 International trade 83
6.1.1 Proposition 1a: Large PGMs resources and reserves in South Africa are likely to lock South Africa in export of primary refined PGMs products. 83
6.1.2 Proposition 1b: Technological know-how will transform South Africa into a net exporter of finished PGMs-related products. 83
6.2 Institutional regime 84

6.2.1 Proposition 2: Progressive policies implemented by the formal institutions will cause gradual diversification of South Africa's PGMs industry into a net exporter of finished PGMs-related products. 84
6.3 Innovative capabilities 85
6.3.1 Proposition 3: Education and innovation strategies in South Africa will likely create diversification of South African PGMs industry. 85
6.4 Relatedness of capabilities 86
6.4.1 Proposition 4: South Africa's PGMs product space network density is likely to sustain diversification and expansion of current PGMs-related products. 86
6.5 Foreign Direct Investment 87
6.5.1 Proposition 5: FDI will likely cause South African PGMs mining sector to diversify into manufacturing and export of finished PGMs products. 87
6.6 Recommendations 88
6.7 Suggestions for future research 89
6.8 Limitations of the study 89
References 90
Appendix A. Participation Information Sheet 92
Appendix A. Informed consent 93
Appendix B. Research instrument 94

List of Tables

Table 1-1. Top ten export commodities for the period January 2015 to June 2021. Source (SARS, 2021) 3
Table 1-2. Definition of terms 7
Table 3-1. Profile of Participants 22
Table 3-2. Strategies to enhance the credibility of the research. 28
Table 3-3. Ethical challenges facing the research and mitigation plans. 29
Table 4-1. Clustering of Proposition 1a codes into code categories and themes 35
Table 4-2. Insights into emerging code categories from participants' perspective with respect to Proposition 1a 35
Table 4-3. Clustering of Proposition 1b codes into code categories and themes 41
Table 4-4. Insights into emerging code categories from participants with respect to Proposition 1b 41

Table 4-5. Clustering of Proposition 2 codes into code categories and themes 47
Table 4-6. Insights into emerging code categories from participants with respect to Proposition 2 48
Table 4-7. Clustering of Proposition 3 codes into code categories and themes 53
Table 4-8. Insights into emerging code categories from participants with respect to Proposition 3 54
Table 4-9. Clustering of proposition 4 codes into code categories and themes.....59
Table 4-10. Insights into emerging code categories from participants with respect to Proposition 4 60
Table 4-11. Clustering of Proposition 5 codes into code categories and themes 65
Table 4-12. Insights into emerging code categories from participants with respect to Proposition 5 65
Table 5-1. Summary of themes associated with drivers of vertical forward integration. 81

List of Figures

Figure 1-1. Annual South African PGMs production and export sales. Source MCSA, 2019..2
Figure 1-2. Total Platinum sales mix for the period 2009 to 2019 in refined PGMs and semi-finished products. Source MCSA, 2019 2
Figure 1-3. PGMs value chain illustrating the research problem, modified from (Juris et al., 2020) 4
Figure 2-1. Conceptual Model on diversification of primary natural PGMs export to PGMs manufacturers derived from the literature review.....19
Figure 3-1. Process map illustrating procedure for data collection and analysis.....26
Figure 4-1. Atlas.ti screen dump illustrating arrangement of in vivo codes by proposition and groupings of in vivo codes into code categories.....32
Figure 4-2. Summary of findings outlining framework of drivers of vertical forward integration and emerging themes in the context of the South African PGMs industry 69
Figure 5-1. Input-output model illustrating dynamics of drivers of vertical forward integration in South Africa's PGMs industry. 80

Chapter 1: Introduction

1.1 Purpose of the study

This research explores the drivers of forward vertical integration to migrate the South African platinum group metals (PGMs) industry from a net exporter of refined and semi-finished PGMs' products to a net exporter of finished PGMs-related products. The drivers of vertical forward integration in the PGMs industry are those factors that will facilitate the accumulation of technological know-how in the PGMs mining sector, leading to the manufacturing and export of finished PGMs-related products. The formal and informal institutional regimes' strength, credibility and participation are vital in formulating, implementing and monitoring the drivers of vertical forward integration to migrate the economies from net exporters of resource-intensive products to net exporters of finished and technologically sophisticated products (Asongu & Tchamyou, 2018; Cortinovis, Xiao, Boschma, & van Oort, 2017; Razmi & Blecker, 2008).

1.2 Context of the study

South Africa produces 90.9% of world PGMs production, followed by Russia at 5.6%, the USA at 1.3%, Zimbabwe at 1.7%, and Canada at 0.4% (Juris et al., 2020). The world share of Palladium production is split between South Africa (38%) and Russia 40% (Juris et al., 2020). However, South Africa produces 71% of Platinum and 80% of Rhodium in world mining output (Juris et al., 2020). The annual PGMs production from 2009 to 2019, supplied by the Minerals Council of South Africa, is depicted in Figure 1-1. For the period, 2009 to 2019, as illustrated in Figure 1-2, South Africa exported 90% of its total annual production in refined and semi-finished PGMs-related products, and 7% of the total production was consumed locally (Minerals Council of South Africa [MCSA], 2019).

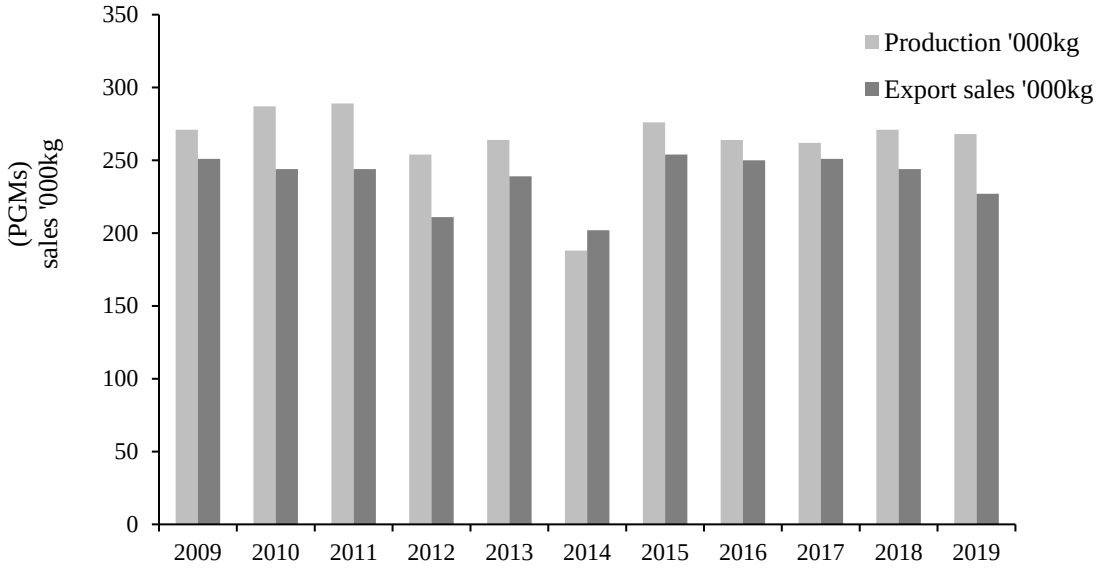

Figure 1-1. Annual South African PGMs production and export sales. Source MCSA, 2019

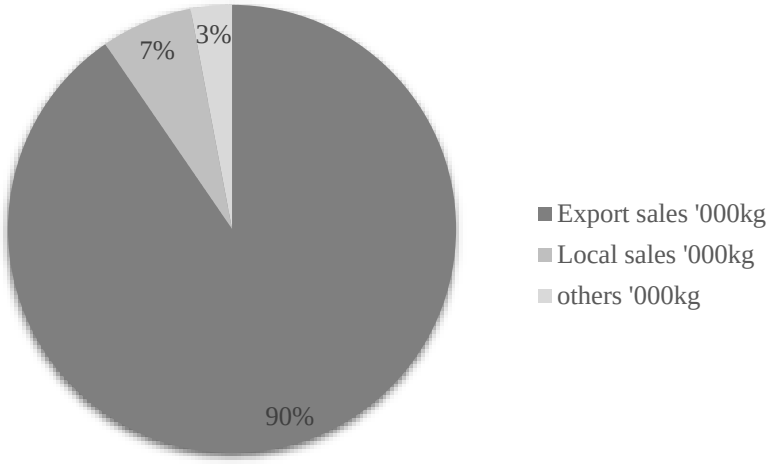

Figure 1-2. Total Platinum sales mix for the period 2009 to 2019 in refined PGMs and semi-finished products. Source MCSA, 2019

The top ten export goods data for the period, January 2015 to June 2021, supplied by the South African Revenue Services and categorised according to the Standard International Trade Classification (SITC) show that primary natural minerals products, refined minerals and semi-finished products make up 87% of export value in South African Rands (ZAR) as shown in Table 1-1. Metalliferous ores (SITC 28), PGMs (SITC 68) and non-monetary trade in gold (SITC 97), including semi-finished products, make a significant proportion of the top ten export mix by value in ZAR. SITC 28, SITC 68, and SITC 97 contributed 25%, 19% and 18%, respectively, from January 2015 to June 2021 (South African Revenue Services [SARS], 2021). The sum of energy minerals, liquid fuels, petroleum oils, and electricity (SITC 32+33+34+35)

accounts for 16% of the top ten export commodities in custom value (ZAR) (SARS, 2021). Vehicles and accessories (SITC 78) and machinery (SITC 74) make up 11% of the export mix and are the smallest by volume (SARS, 2021). This export mix highlights the lack of, or slow process of, product diversification in the South African economy.

Table 1-1. Top ten export commodities for the period January 2015 to June 2021. Source (SARS, 2021)

Label	Code (SITC)	Export customs value in ZAR '000 000	The proportion of top ten export goods (%)
Iron, chrome & manganese	28	692 670	25
Iron & steel	67	251 955	9
Energy minerals & products	32+33+34+35	455 371	16
PGMs	68	541 852	19
Non-monetary trade in gold and metals	97	492 097	18
Motor-vehicles & machinery	78+ 74	315 493	11
Vegetables and fruits	05	55 171	2
Total		2 804 608	100%

The PGMs production and export data and the export mix of the top 10 commodities by ZAR value show that South Africa is a net exporter of resource-intensive products and a net importer of finished and technologically sophisticated products.

1.3 Research problem

Insights from South Africa's PGMs production and export data for the period 2009 and 2019 (Figure 1-1), supported by the top ten export goods mix data for the period January 2015 to June 2021 (Figure 1-2), show that the South African PGMs industry is locked in mining and the export of refined and semi-finished PGMs-related products (MCSA, 2019; SARS, 2021). South Africa is showing specialisation in exports of resource-intensive goods similar to the South East Asian economies before World War 2. According to Bassino and Williamson (2015), specialisation in the export of resource-intensive goods reallocates the factors of production from manufacturing to the lucrative mining industry, causing stagnant economic growth. The PGMs value chain in Figure 1-3 illustrates the research problem.

The main research problem is to explore the drivers of vertical forward integration to migrate the South African PGMs industry from a net exporter of refined and semi-finished PGMs-related products to an exporter of finished PGMs-related products.

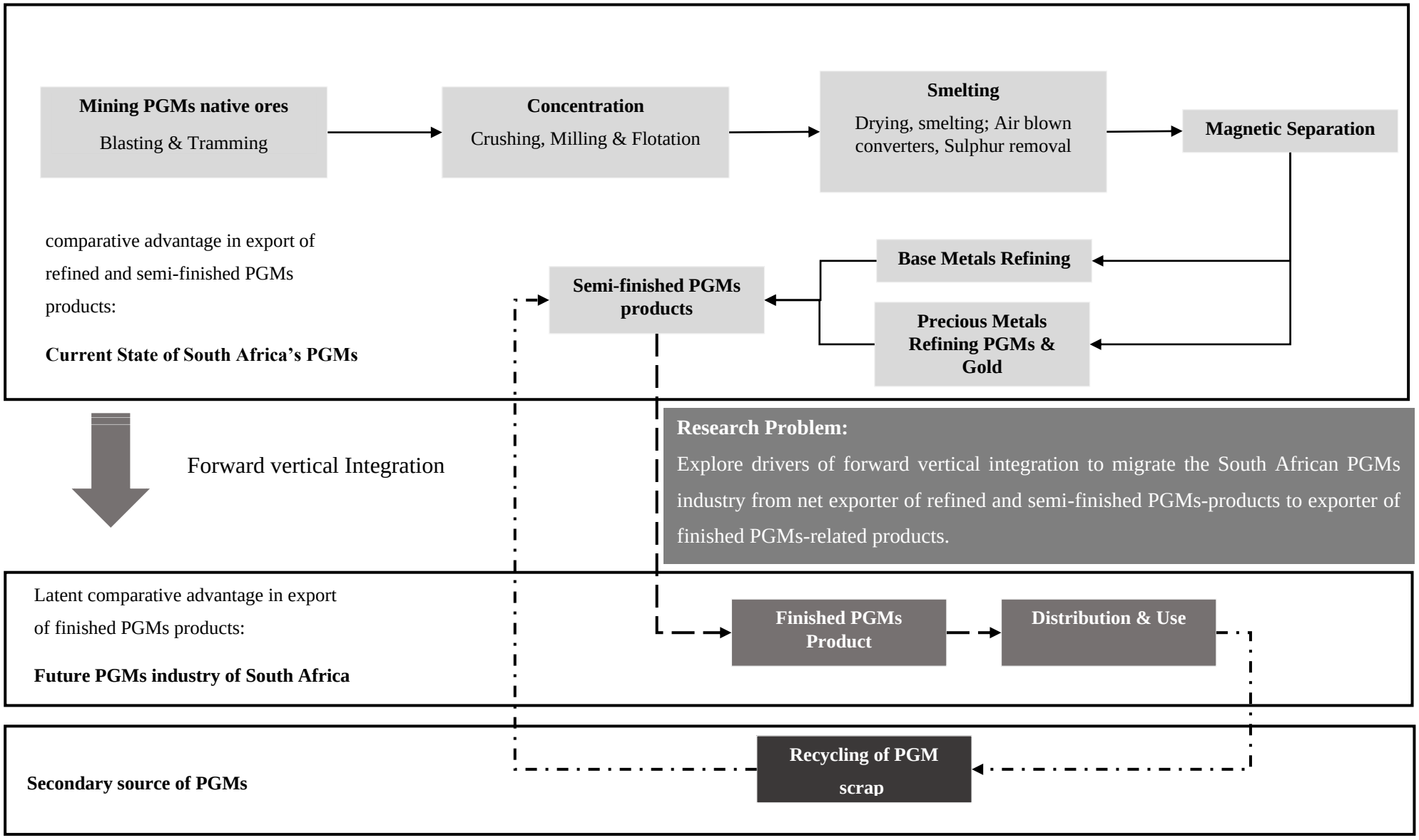

Figure 1-3. PGMs value chain illustrating the research problem, modified from (Juris et al., 2020)

1.4 Research objectives

The objectives of the research are:

- To identify drivers of vertical forward integration from the literature review in the context of natural resource-based economies
- To explore the themes around drivers of vertical forward integration in the context of the South African Platinum industry through qualitative research.
- To develop a working framework illustrating linkages between the drivers of vertical forward integration and how these drivers will work to transform South Africa's PGMs industry export pattern.

1.5 Research propositions

The following research propositions create the framework for this study:

- Proposition 1a: Large PGMs resources and reserves in South Africa are likely to lock South Africa in the export of primary refined PGMs products.
- Proposition 1b: Technological know-how will transform South Africa into a net exporter of finished PGMs-related products.
- Proposition 2: Progressive policies implemented by the formal institutions will cause the gradual diversification of South Africa's PGMs industry into a net exporter of finished PGMs-related products.
- Proposition 3: Education and innovation strategies in South Africa will likely create the diversification of the South African PGMs industry.
- Proposition 4: South Africa's PGMs product space network density is likely to sustain the diversification and expansion of current PGMs-related products.
- Proposition 5: FDI will likely cause the South African PGMs industry to diversify into manufacturing and export of finished PGMs products.

1.6 Significance of the study

Nazarczuk et al. (2018) note that export specialisation in goods with comparative advantage contributes positively to the value of exports per capita but has the downside of a lock-in effect in the country's export mix. However, countries and industries, particularly the South African PGMs industry, with comparative advantage in the export of resource-intensive goods, can develop a comparative advantage in exports of technologically sophisticated goods by

accumulating technological know-how through dynamic export-led-industrialisation policies (Bassino & Williamson, 2015; Hausmann & Klinger, 2007). According to Nazarczuk et al. (2018), export-led industrialisation policies must build the capacity to find new industries or product groups to offer to foreign markets.

This research may be helpful to governments and businesses to:

1. Understand what gives the South African PGMs industry a comparative advantage.
2. Formulate export-led industrialisation policies to industrialise the PGMs industry.
3. Identify other sectors with opportunities for vertical forward integration.

1.7 Delimitations of the study

This research seeks to identify drivers of vertical forward integration in the South African PGMs industry to release latent comparative advantage in the production of finished PGMs-related products.

The study will interview senior manager in Platinum and Gold mining houses in South Africa due to their accessibility and their proximity to the formulation and rollout of company strategies. The study excludes interviews of participants from formal institutions, regulatory bodies, and the manufacturing sector due to time limitations and the scope of the project.

1.8 Assumptions

The following research assumptions were made:

1. The participants understand macro-environment factors affecting the South African PGMs industry.
2. The participants know the industrial uses of PGMs and are familiar with the PGMs' value chain.
3. Global demand for platinum goods will stay positive.
4. The respondents immersed themselves in the interview and provided truthful and accurate perspectives based on their reality or their company strategy.

1.9 Definition of the terms

Table 1-2. Definition of terms

Term	Definition
Comparative advantage	Country's ability to produce goods at a lower opportunity cost of production relative to its trading partners or the ability to manufacture the same amount of goods using fewer factors of production than the trading partners. According to Leamer (1984), comparative advantage develops when the country is relatively well endowed with a factor of production that is used intensively to produce given goods compared to its trading partners.
Formal institution	Refers to the institution that embodies structured arrangements such as government policy or competition regulations (Cortinovis, Xiao, Boschma, & van Oort, 2017)
Informal institutions	They are formed by relationships that are defined by culture, religion, and social values (Cortinovis et al., 2017)
PGMs	PGMs, namely Ru, Rh, Pd, Os, Ir and Pt, are found in trace amounts in rocks; they occur in their native metal state and or in solid solutions with sulfur-bearing minerals (Juris et al., 2020).
Vertical forward integration	Refers to taking part in activities downstream of the supply chain, and it gives the sector/business the ability to control the demand side and diversify their products (Lin, Parlaktürk & Swaminathan, 2014)

1.10 Conclusion to Chapter 1

The purpose of this study is to explore the drivers of forward vertical integration to migrate the South African platinum group metals (PGMs) industry from a net exporter of refined and semi-finished PGMs' products to a net exporter of finished PGMs-related products. The Minerals Council of South Africa (2019) indicated that South Africa exported 90% of its total annual production in refined and semi-finished PGMs-related products, and 7% of the total production was consumed locally for the period 2009 to 2019. According to the South African Revenue Services (2021), primary natural minerals products, refined minerals and semi-finished products make up 87% of export value in South African Rands (ZAR) of the top ten export goods.

The annual PGMs production for period 2009 to 2019 and the top ten export goods data for the period, January 2015 to June 2021 show that South Africa is specialising in exports of resource-intensive goods similar to the South East Asian economies before World War 2. According to Bassino and Williamson (2015), specialisation in the export of resource-intensive goods reallocates the factors of production from manufacturing to the lucrative mining industry, causing stagnant economic growth.

Therefore, the main research problem is to explore the drivers of vertical forward integration to migrate the South African PGMs industry from a net exporter of refined and semi-finished PGMs-related products to an exporter of finished PGMs-related products. The objectives of the study are:

- To identify drivers of vertical forward integration from the literature review in the context of natural resource-based economies
- To explore the themes around drivers of vertical forward integration in the context of the South African Platinum industry through qualitative research.
- To develop a working framework illustrating linkages between the drivers of vertical forward integration and how these drivers will work to transform South Africa's PGMs industry export pattern.

The study may be helpful to governments and business by exploring how the South African PGMs industry can develop comparative advantage in export of technologically sophisticated PGMs related goods and identify other sectors with opportunities for vertical forward integration.

The study is designed to interview senior management in Platinum and Gold mining houses in South Africa due to their accessibility and their proximity to the formulation and rollout of company strategies. The study excludes interviews of participants from formal institutions, regulatory bodies, and the manufacturing sector due to time limitations and the scope of the project. The study assumes that the selected participants are familiar with micro and macro-environmental factors affecting the South Africa's PGMs industry and the global demand for platinum will stay positive.

Chapter 2: Theoretical framework

This chapter introduces the literature for drivers of vertical forward integration required to develop manufacturing industries in natural resource-based economies. The chapter will conclude with a working theoretical framework showing linkages between these drivers and how they function to transform economies exporting natural resource-intensive goods to exporting technologically sophisticated products.

2.1 International Trade Theory

The generally accepted consensus in international trade theory among scholars like Leamer (1995), Leamer (1984), and Nazarczuk, Umiński and Gawlikowska-Hueckel (2018) is that a comparative advantage determines the flow of goods between trading countries. For example, a country will export goods with a lower opportunity cost of production and import goods with higher opportunity costs. Leamer (1984) notes that comparative advantage develops from factor intensity of production inputs and commodity endowment. Contrary to Leamer (1984), Davis (2010) and Deardorff (2007) attribute comparative advantage to technological differences between trading partners.

The Heckscher – Ohlin (OH) trade model and the Ricardian trade model were explored to understand international trade in mineral commodities.

2.1.1 Heckscher – Ohlin model

The Heckscher – Ohlin (HO) model predicts that, in an open economy, a country will develop a relative comparative advantage over its trading partners when it has a sizeable immobile factor endowment, assuming that the technologies exploiting that immobile factor are similar (Leamer, 1984, 1995). Therefore, natural resources-rich countries will specialise in exporting natural resource-intensive goods and importing value-added goods from countries with significant capital resources and developed human capital factor intensity (Leamer, 1984, 1995).

According to Nazarczuk et al. (2018), export specialisation in natural resource-intensive goods contributed positively to the value of exports per capita in Polish countries between 2004 to 2015. This finding by Nazarczuk et al. (2018) supports the HO model's assumption that a country will have a comparative advantage in goods that are manufactured from relatively well-endowed immobile resources compared to its trading partners (Leamer, 1984).

Although specialisation in primary resource-intensive goods positively contributes to the country's exports per capita, it has a downside. It impairs the country's latent ability to export value-added products from its well-endowed natural resources (Nazarczuk, Umiński, & Gawlikowska-Hueckel, 2018). Another downside of excessive specialisation in primary natural resource products is deindustrialisation during commodity booms, as illustrated by Southeast Asia's economies before 1913 (Bassino & Williamson, 2015). The country specialising in resource-intensive goods exports will diversify to value-added exports when it achieves a significant increase in knowledge and institutional capital accumulation (Bassino & Williamson, 2015; Hausmann & Klinger, 2007).

Based on the theoretical framework of the HO trade model, the following proposition is formulated:

Proposition 1a: Large PGMs resources and reserves in South Africa are likely to lock South Africa in the export of primary refined PGMs products.

2.1.2 The Ricardian model

According to the Ricardian trade model, the flow of goods between trading partners is determined by the differences in technology (Davis, 2010; Deardorff, 2007). Countries with superior technological capabilities will develop a comparative advantage in manufacturing and exporting technologically sophisticated goods. The level of technological advancement in the country is dependent on local enterprises' capabilities to develop new technologies, absorb new technologies from abroad, and accumulate technology over time (Petralia, Balland, & Morrison, 2017).

Eaton and Kortum (1999) and Petralia et al. (2017) note that most innovative countries produce a large share of the world's most capital and skill-intensive products while less innovative countries export resource-intensive products and low-skill products. Contrary to the HO model, the Ricardian model's comparative advantage is determined by highly mobile technological resources. Patents can immobilise and protect technology inside the home country. However, weak enforcement of patents in developing countries allows imitation and diffusion of innovations and knowledge across home boundaries weakening their comparative advantage (Eaton & Kortum, 1999).

Therefore, countries should engage in the dynamic improvement of their technologies through collaborative learning and continuous knowledge creation, and absorption of foreign knowledge to get ahead of trading partners and develop comparative advantage (Eaton & Kortum, 1999; Maskell & Malmberg, 1999). According to Eaton and Kortum (1999), countries that climb the technology ladder develop comparative advantage and succeed in diversifying their export mix and economies.

Following the assumptions and prediction of the Ricardian trade model, technological development will enable the country to migrate from resource-intensive goods to technologically advanced goods in a gradual manner (Eaton & Kortum, 1999; Maskell & Malmberg, 1999; Petralia et al., 2017). The following proposition was formulated from the above insights:

Proposition 1b: Technological know-how will transform South Africa into a net exporter of finished PGMs-related products.

2.1.3 Summary of International Trade Theories

The HO and Ricardian trade models explain the trade patterns and export mix between developing and developed countries. The HO model states that a country will specialise in goods that intensively use factors it is well endowed with, compared to its trading partners (Leamer, 1984). The HO model predicts that developing countries will specialise in the export of resource-intensive goods. The Ricardian trade model states that the level of technological development gives a nation a comparative advantage in the export of value-added products. As a result, developed countries produce a large share of the world's most capital and skill-intensive products while developing countries export resource-intensive products.

Unfortunately, specialisation in primary natural mineral products prevents developing countries from diversifying their export mix. However, Eaton and Kortum (1999) note that developing countries can change their export mix along a gradual trajectory through the dynamic improvement of their technologies through collaborative learning, continuous knowledge creation, and the absorption of foreign knowledge.

The following propositions were formulated from the HO and Ricardian trade models:

Proposition 1a: Large PGMs resources and reserves in South Africa are likely to lock South Africa in the export of primary refined PGMs products.

Proposition 1b: Technological know-how will transform South Africa into a net exporter of finished PGMs-related products.

2.2 Trade diversification drivers

Trade diversification in developing countries is crucial for inclusivity in economic development and the sustainable development of non-renewable resources. Following Hidalgo, Klinger, Barabási, & Hausmann (2007) and Hausmann and Klinger (2007) arguments, the ability to diversify the export mix of a developing country will depend on the country's capability to re-arrange existing transforming and transformed inputs to produce new products and services for the economy. Several scholars note that the capability to re-arrange factor inputs is driven by: (i) institutional regimes; (ii) innovative capabilities; (iii) relatedness of capabilities; and (iv) foreign direct investment.

2.2.1 Institutional regime

Formal institutional regimes should enable competitive forces in the economy to drive diversification by adopting policies that encourage; liberalisation of markets, foreign direct investment (FDI), endogenic and exogenic creation of knowledge and technology, government accountability, development and expansion of modern infrastructure (Asongu & Tchamyou, 2018; Razmi & Blecker, 2008). Countries increase their capital-raising capacity to develop innovative capabilities when they demonstrate financial credibility through targeted responsible policy implementation (Asongu & Tchamyou, 2018).

Cortinovis et al. (2017) study on regional impacts of the competency of formal institutions on diversification in 118 European countries proposes that the competency of government and bonding social capital has a lesser impact on diversification into new sectors in contrast to bridging social capital. Inclusive economic participation and trust are dominant in bridging social capital and increasing the success rate of diversifying into new products and services (Cortinovis et al., 2017). Trusts and economic inclusivity increase the country's financial credibility for building its capacity to attract FDI.

According to Cortinovis et al. (2017), the impact of bridging capital on diversification is amplified when government effectiveness is low and reduces when the competency of the government increases. Therefore, countries with poor governments and strong bridging social capital can still diversify into new sectors, with the cautionary note that informal institutions

cannot exclusively substitute high-quality formal institutions (Cortinovis et al., 2017). In contrast, the impact of bonding capital on diversification is negative when the quality of government is low and insignificant when the quality of government is high (Cortinovis et al., 2017). Based on this theoretical consideration, the following proposition was formulated:

Proposition 2: Progressive policies implemented by the formal institutions will cause gradual diversification of South Africa's PGMs industry into a net exporter of finished PGMs-related products.

2.2.2 Innovative capabilities

2.2.2.1 Education and innovative strategies

Leamer (1995) points that professional and skilled human capital plays a role in determining trade patterns. Similarly, Asongu and Tchamyou (2018), and Maskell and Malmberg (1999) argue that education gives the country the capability to continuously create new knowledge and technology. Education gives the country abilities and capabilities to absorb foreign technology and diversify its export mix. Asongu and Tchamyou (2018) note that South Korea's education and innovation policies were targeted at improving strategic human resources to evolve with constantly improving economic and political institutional environments. South Korea spends 3% of its annual GDP on R&D (Asongu & Tchamyou, 2018). Asongu and Tchamyou's (2018) observations on South Korean education and innovative strategies indicate that the policymakers identified specific factors of production they have in abundance and developed human resources to acquire tacit knowledge and create inimitable combinations of those factors.

Maskell and Malmberg (1999) argue that government policies must encourage interactive learning processes and knowledge creation between enterprises, which are important for sharing of tacit knowledge. Asongu and Tchamyou (2018) reiterate Maskell and Malmberg's (1999) arguments that governments' vocational education training policies must be in the interest of the country's economic development strategy and promote industry linkages through collaborative programmes between future employers. Tacit knowledge is crucial for the consolidation of new technologies and for giving the country's human resources a technological know-how capacity to create new products and services (Asongu & Tchamyou, 2018).

According to Asongu and Tchamyou (2018), South Korea's innovation strategy in the early phases of industrialisation was imitation-to-innovation, exploiting the weak enforcement of patents in developing countries. In the current environment of knowledge-based economies and the 4th industrial revolution (4IR) imitation-to-innovation strategies are no longer effective (Gao, 2018). Multinational enterprises (MNEs) have developed competencies to understand the capabilities of host countries and may choose not to share key technologies with host countries (Gao, 2018). In cases where the host country has under-developed resources and capabilities, the MNEs will adopt brownfields or make acquisitions through the foreign direct investment (FDI) entry mode giving MNEs total control and protection of their technologies and innovations significantly reducing imitation risks (Tulung, 2017).

In Gao (2018) the analysis of experiences by Chinese telecom equipment enterprises to close the technological gap with developing nations' MNEs, he proposes an endogenic innovation-based differentiation strategy in the early phases of industrialisation. According to Gao (2018), an endogenic innovation-based differentiation strategy entails developing core technologies and disrupting innovative low-cost offerings and superior customer service (Gao, 2018). Gao (2018) and Asongu and Tchamyou (2018) argue that governments need to implement policies that encourage enterprises to invest heavily in R&D in their value chains to achieve sustainable low-cost advantage with superior offerings and customer service. Gao (2018), like Maskel and Malmberg (1999), also advocates achieving a continuous constant rate of technological innovation to maintain comparative advantage in trade.

Asongu and Tchamyou's (2018) observation in the South Korea study observed that the success and speed of implementation of education and innovative strategies can be amplified by the development of adequate information and communication technology (ICT) networks. ICT networks enable the sharing of information, the creation of linkages between government and business, and social capital. It also facilitates the country's ability to combine its existing capabilities in an inimitable manner to create new sectors. To enable education and innovation strategy, the South Korean ICT strategy hinges around three areas (Asongu & Tchamyou, 2018): (i) an industrial ICT policy framework that facilitates human resource development, access to venture capital to drive entrepreneurship, and collaborative R&D in the country; (ii) the regulatory and fiscal ICT policy framework drives the opening up of the economy and loosening government controls and privatisation to democratise goods and services and (iii) an active information ICT policy framework targeted at building world-class ICT infrastructure increasing the accessibility of knowledge. Based on the above literature review that; education

and innovation capabilities propel a country towards a path of manufacturing and exporting value-added products the following proposition was made:

Proposition 3: Education and innovation strategies in South Africa will likely create the diversification of the South African PGMs industry.

2.2.3 Relatedness of capabilities

There is existing scholarly awareness that developing economies tend to diversify into new products and services that use transforming input capabilities similar to those that already exist in the local economy (Boschma, 2017), (Coniglio, Lagravinese, Vurchio & Armenise, 2018). Boschma (2017) and Coniglio et al. (2018) affirm Hidalgo et al. (2007) and Hausmann and Klinger's (2007) arguments that existing capabilities like human capital, technology, and the institutional regime can easily be arranged in different ways to produce new products. Products are deemed to be related if they use the same input capabilities. Relatedness between products is caused by the intensity of factors, level of technological advancement, primary inputs and outputs involved in their value chain, and enabling institutional regimes (Hidalgo, Klinger, Barabási & Hausmann, 2007). Hidalgo et al. (2007) use the construct 'product space' to describe the degree of relatedness between products. According to Hidalgo et al. (2007), resource-intensive goods and related semi-manufactures occupy less connected product space and sophisticated technological products are located in densely connected product space.

Hidalgo et al. (2007) and, Hausmann and Klinger (2007) demonstrated that countries producing densely connected products can piggyback from existing capabilities and diversify into more sophisticated goods. However, countries producing less connected products find it more difficult to make significant jumps to producing sophisticated goods (Hidalgo et al., 2007) and (Hausmann & Klinger, 2007). Therefore, existing capabilities are a limiting factor in developing and sustaining value-adding activities downstream of the supply chain.

Product space networks guide policymakers to develop industrial policies targeting sectors that are more likely to succeed based on their existing capabilities resulting in the gradual diversification of the economy (Coniglio et al., 2018). The product space framework supports Maskel and Malmberg's (1999) deductions that countries require a continuous constant rate of technological innovation to reveal and maintain comparative advantage in trade. According to Coniglio's et al. (2018) analysis, countries enable their latent comparative advantage by diversifying to less complicated products using existing capabilities and moving incrementally

up the development ladder to produce technologically sophisticated goods as they accumulate technological know-how. Based on the above literature review that a diversification trajectory of a country will be largely determined by existing specialisation which is confined to existing capabilities and comparative advantage (Coniglio et al., 2018), the following proposition was formulated:

Proposition 4: South Africa's PGMs product space network density is likely to sustain the diversification and expansion of current PGMs-related products.

2.2.4 Foreign Direct Investment

Outward foreign direct investment (OFDI) is seen by many as a physical capital flight risk, a cause of the deindustrialisation of home economies, and an impediment to diversification and economic development (Lim & Teo, 2019). However, recent empirical studies in developing countries such as China shows that OFDI promotes domestic innovation when it is managed well by governments (Li, Strange, Ning & Sutherland, 2016). According to Lim and Teo (2019), emerging economy multinational enterprises (EMNEs) contributed to approximately a third of the world's OFDI. Developing countries seeking economic development through innovative strategies encourage EMNEs' OFDI growth strategies with their accumulated foreign exchange reserves (Lim & Teo, 2019).

During OFDI activities toward developed countries, EMNEs increase and capture value by purchasing foreign technology and gaining access to high-intensity factor inputs (Dong, Miao, & Zhang, 2021), (Lim & Teo, 2019). The EMNE's host country benefits from OFDI activities through the reversal of technology spillover (Dong et al., 2021). Institutional pressure such as the expectation on EMNEs to engage in sustainable green economies to gain legitimacy once they cross borders benefits the EMNE host countries with green innovation spillover (Khan Muhammad, Ali Syed, Yang, Ali & Sarwar, 2020). Green innovation capabilities will give the host country the ability to diversify in green sectors such as the recycling of products, green energy, and other technologies of the future.

Inward foreign direct investment (IFDI) can be harmful to incumbent enterprises by increasing competitive forces (Jin, García & Salomon, 2019). According to Jin et al. (2019), low number of patents and new products registered by local enterprises indicate that they are unable to compete against foreign multinational enterprises (MNEs) due to their superior technology. The study of 28 European Union (EU) Member States for the period 2013 to 2016 supports

scholarly views that IFDI brings new knowledge and technology to host countries and contributes positively to the development of innovative capabilities and strengthens knowledge-based sectors (Andrijauskiene & Dumčiuvienė, 2019). The above studies on the role of FDI in the diversification of the economy led to the formulation of the following proposition.

Proposition 5: FDI will likely cause the South African PGMs industry to diversify into manufacturing and export of finished PGMs products.

2.2.5 Summary of trade diversification drivers

Hidalgo et al. (2007) and Hausmann and Klinger (2007) defined diversification as a process of using existing capabilities in new combinations to produce new goods and services. According to Asongu and Tchamyou (2018), to increase the success of export mix diversification the country needs to invest and develop innovative capabilities through education and innovation strategies. Asongu and Tchamyou (2018) note that education and innovation policies enable strategic human resources to: (i) evolve with constantly improving economic and political institutional environments; (ii) continuously create new knowledge, new technologies and absorb foreign innovation. According to Maskell and Malmberg (1999), innovative capabilities give the host country a comparative advantage in technology and allow it to diversify and specialise in sophisticated high-technology goods.

As noted by Hidalgo et al. (2007) and Hausmann and Klinger (2007), related capabilities are key for the successful creation of new sectors and products because they reduce the risk of failure by taking an incremental approach to diversification using existing capabilities and learning along the technological ladder.

Asongu and Tchamyou (2018) and Razmi and Blecker (2008) note that formal and informal institutions enable trade mix diversification by adopting market-orientated policies. Credible institutions are able to raise foreign capital for their economic development strategies (Asongu & Tchamyou, 2018). FDI is seen by others as harmful to economies −OFDI is considered to be physical capital and human capital flight risk, (Lim & Teo, 2019) whereas IFDI pacifies local enterprises by increasing competitive forces through their superior technologies (Jin et al., 2019). Dong et al. (2021) and Andrijauskiene and Dumčiuvienė (2019) state that FDI brings new knowledge and technology to host countries thus driving their trade mix diversification.

2.3 Conclusion to Chapter 2

International trade theory models, the HO model, and the Ricardian Model give context to the trade patterns in developing countries with large mineral resource endowments. The HO model predicts that developing countries with large natural resource endowments develop a comparative advantage in exports of resources-intensive products. However, the Ricardian Model ascribes comparative advantage in export trade to technological differences between countries. Countries below the technological ladder will export primary natural resource-intensive products and countries high in the technology ladder will export sophisticated technological products and services. However, Eaton and Kortum (1999), Maskel and Malmberg (1999), and Gao (2018) argue that developing countries can change their trade mix to value-added products by continuous development of new knowledge and new technology through endogenic and exogenic education and innovation strategies. International trade theories led to the development of the two propositions below:

Proposition 1a: Large PGMs resources and reserves in South Africa are likely to lock South Africa in the export of primary refined PGMs products.

Proposition 1b: Technological know-how will transform South Africa into a net exporter of finished PGMs-related products.

The theoretical framework of drivers of vertical forward integration is shown in Figure 2-1. The drivers of vertical forward integration are: (i) institutional regime; (ii) innovative capabilities; (iii) relatedness of capabilities; and (iv) the role of foreign direct investment (FDI).

According to Asongu and Tchamyou (2018), Cortinovis et al. (2017), and Razmi and Blecker (2008), formal institutional and informal institutions drive diversification by adopting policies that encourage the liberalisation of markets, FDI, absorption of foreign technologies and knowledge, government accountability, development, and the expansion of modern infrastructure. According to Gao (2018), an endogenic innovation-based differentiation strategy gives the country inimitable innovative capabilities and sustainable comparative advantage (Figure 2-1). The following proposition was formulated to test the ability of South Africa's institutions to drive the diversification of trade in the PGMs industry.

Proposition 2: Progressive policies implemented by the formal institutions will cause the gradual diversification of South Africa's PGMs industry into a net exporter of finished PGMs-related products.

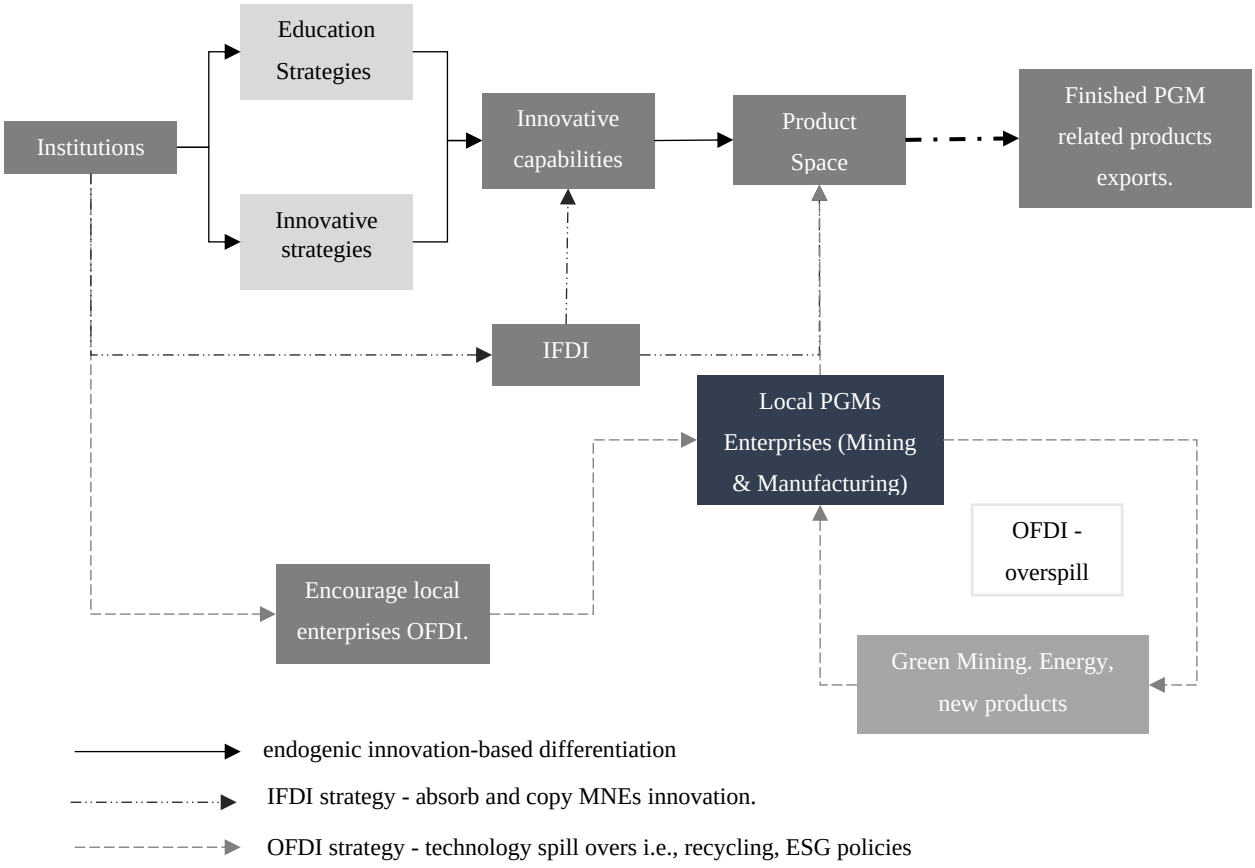

Figure 2-1. Conceptual Model on diversification of primary natural PGMs export to PGMs manufacturers derived from the literature review.

Innovative capabilities drive trade diversification by developing strategic human resources capability to create and absorb new technologies (Leamer, 1995), (Maskell & Malmberg, 1999), (Asongu & Tchamyou, 2018). Institutions encourage and develop innovative capabilities through education and innovative strategies, Figure 2-1. South Korea demonstrated the value of adopting focused education and innovative strategies coupled with effective communication technology network strategies to develop its innovative capabilities (Asongu & Tchamyou, 2018). The following proposition was created to test the influence of innovative capabilities on diversification.

Proposition 3: Education and innovation strategies in South Africa will likely create diversification of the South African PGMs industry.

Developing countries that were successful in diversifying their economies did so in an incremental approach by manufacturing new products and services that used existing capabilities, Boschma (2017) and Coniglio et al. (2018), reducing the risk of new product failure, Figure 2-1. The proposition below tests the likelihood of creating new sectors and products by combining existing capabilities.

Proposition 4: South Africa's PGMs product space network density is likely to sustain the diversification and expansion of current PGMs-related products.

Although FDI has its own disadvantages, it brings new knowledge, technology, and green innovation to host countries (Dong et al., 2021), (Lim & Teo, 2019), (Andrijauskiene & Dumčiuvienė, 2019) as illustrated in Figure 2-1. During OFDI activities towards developed countries, EMNEs can have full access to foreign technology and high-intensity factor inputs to pass them over to the host country through a reversal of technology spillover (Dong et al., 2021). However, during IFDI activities, knowledge and technology transfer to the local economy is limited by the entry mode of MNE, (Tulung, 2017).

The theoretical framework of the role of FDI in the diversification of the economy led to the formulation of the following proposition:

Proposition 5: FDI will likely cause the South African PGMs industry to diversify into manufacturing and export of finished PGMs products.

The above theoretical framework, Figure 2-1, will be used to cross-validate and make sense of the emergent themes and theories that will come from the qualitative research data collection and analysis as the study unfolds.

Chapter 3: Material and Methods

For the period between 2009 and 2019, 90% of total PGMs production in South Africa was exported and only 7% of total production was consumed locally MCSA (2019). This trade pattern impairs South Africa's latent comparative advantage in the export of finished PGMs-related products. Therefore, the main research problem is to define the drivers of vertical forward integration to migrate the South African PGMs industry from a net exporter of refined and semi-finished PGMs-related products to an exporter of finished PGMs-related products.

The qualitative research methodology was used for this research to establish an in-depth understanding of drivers required to change South Africa's PGMs industry export mix to exports of finished PGMs-related products.

The theoretical framework explored in Chapter 2, indicates that there are strong relationships between drivers of vertical forward integration and possible causation between the drivers, Figure 2-1. Therefore, these drivers are expected to modify the impacts of each other on PGMs-related product trade patterns. South Africa, being an open economy, will be more challenging to understand what shapes the PGMs trade mix because of PGMs world demand, PGM basket price fluctuations, world trade policies, global environmental policies, and transportation costs. Therefore, there will be multiple understandings of the drivers of forward vertical integration.

Interpretive research is suitable for cases, as above, where there are multiple interpretations and solutions for one phenomenon (Rehman & Alharthi, 2016). Therefore, this research was carried out in an interpretive research paradigm to understand the drivers of forward vertical integration.

3.1 Study design

The qualitative research design choice is informed by the research question or problem, the research paradigm, and the researcher's training and experience (Creswell, Hanson, Clark Plano, & Morales, 2007). According to Creswell et al. (2007), grounded theory design fits the research problem outlined in Chapter 1 because: (i) it is descriptive and inductive; (ii) the primary objective of the research is to develop an in-depth understanding of drivers of vertical forward integration; (iii) propositions seek to test which drivers are likely to cause diversification in SA; and (iv) it will allow the researcher to understand South African PGMs export mix through the lens of the industry players.

3.2 Participants' selection and population size

Field data collection using the grounded theory has the flexibility to increase and do repeated interviews until no new concepts emerge from the data (Harris, 2015). Therefore, it is not easy to determine the sample size prior to the commencement of data collection (Dworkin, 2012), (Harris, 2015). This research ensured enough participants to get close to the saturation point as recommended by Harris (2015). According to Harris (2015) and Dworkin (2012), the saturation point depends on several factors such as: (i) budget, logistics and schedule of the study; (ii) whether the sample is homogenous or heterogeneous; (iii) different levels of subject matter understanding of the participants; and (iv) ability of the researcher to identify saturation point.

The purposive sampling method was used to select a sample of four senior managers in the PGMs mining sector population. Their selection was based on the following criteria: in-depth experience of PGMs macro-environment factors affecting the PGMs industry, the proximity to corporate decision-making level, their accessibility and availability, and the time limitation of the study. Four senior managers were invited for a structured interview, Table 3-1. Three responded and were interviewed. The fourth participant was unavailable due to logistics. A saturation point was observed after conducting the second interview; however, a third interview was carried out to confirm it. This interview, from the third participant, was included in the results. The saturation point was reached early because of the homogeneity of the sample, all participants were from the mining discipline.

Table 3-1. Profile of Participants

Participant Identification	Responded	Mining Sector	Total Years in Mining Industry
Participant 1	Yes	Gold, PGMs, Iron Ore	23
Participant 2	Yes	Gold, PGMs	29
Participant 3	No	PGMs	
Participant 4	Yes	PGMs & Gold	23

The participation information letter and the informed consent letter, **Appendix A**, were forwarded to selected participants to encourage participation in the study.

3.3 Data collection

Four senior managers from Platinum and Gold mining houses were contacted telephonically and by e-mail. Three were scheduled for interviews Table 3-1. Structured interviews were held on Microsoft Teams with recorded verbatim transcripts. Each interview lasted approximately 50 minutes and was conducted in English. The process of data collection and validation is illustrated in Figure 3-1.

The propositions and research questions are shown in the research instrument, **Appendix B**. Research instrument. The five drivers of vertical forward integration and related propositions and insight-seeking questions are listed below:

1. International trade
   1.1. Proposition 1a: Large PGMs resources and reserves in South Africa are likely to lock South Africa in the export of primary refined PGMs products.
   Research questions:
      - What do you think about the sustainability of SA's strategic position as the number one exporter of PGMs?
      - Is the position good for the country?
   1.2. Proposition 1b: Technological know-how will transform South Africa into a net exporter of finished PGMs-related products.
   Research questions:
      - How would you describe South Africa’s local capability to develop its own technologies and absorb foreign technology?
      - What is lacking to develop these capabilities?
2. Institutional regime
   2.1. Proposition 2: Progressive policies implemented by the formal institutions will cause the gradual diversification of South Africa’s PGMs industry into a net exporter of finished PGMs-related products.
   Research questions:
      - What is the role of government institutions in diversifying the PGMs industry?
      - How do you feel about the role of business institutions in the South African PGMs sector?

3. Innovative capabilities

3.1. Proposition 3: Education and innovation strategies in South Africa will likely create diversification of the South African PGMs industry.

Research questions:

- What are your feelings about South Africa's education and innovation strategies to build innovative capabilities?
- What can be done to improve the impact of these strategies to diversify the PGMs industry?

4. Relatedness of capabilities

4.1. Proposition 4: South Africa's PGMs product space network density is likely to sustain the diversification and expansion of current PGMs-related products.

Research questions:

- What is your feeling about the relationship between products manufactured in South Africa and its PGMs endowment?
- What is required to increase the relatedness of capabilities in the South African PGMs value chain?

5. Foreign Direct Investment

5.1. Proposition 5: FDI will likely cause the South African PGMs mining sector to diversify into manufacturing and the export of finished PGMs products.

Research questions:

- How do you feel about outward the impact of FDI on knowledge-creation and innovation in South Africa's PGMs industry?
- How do you feel about inward FDI on knowledge-creation and innovation in SA PGMs industry?

3.4 Data Analysis

Harris (2015) notes that the inductive data analysis method is suitable for grounded theory research as it allows themes to emerge from the data. The inductive method will allow the researcher to identify new drivers of diversification in the South African PGMs industry not discussed in the literature review. Coding was done using in vivo method using verbatim

transcripts in Atlas.ti software. In vivo coding is descriptive and reflective of what the participant said, reducing the researcher's subjectivity (Harris, 2015). The codes were collapsed into categories by looking for links and relationships leading to the emergence of themes (Harris, 2015). The process followed to analyse the data is illustrated in Figure 3-1 below.

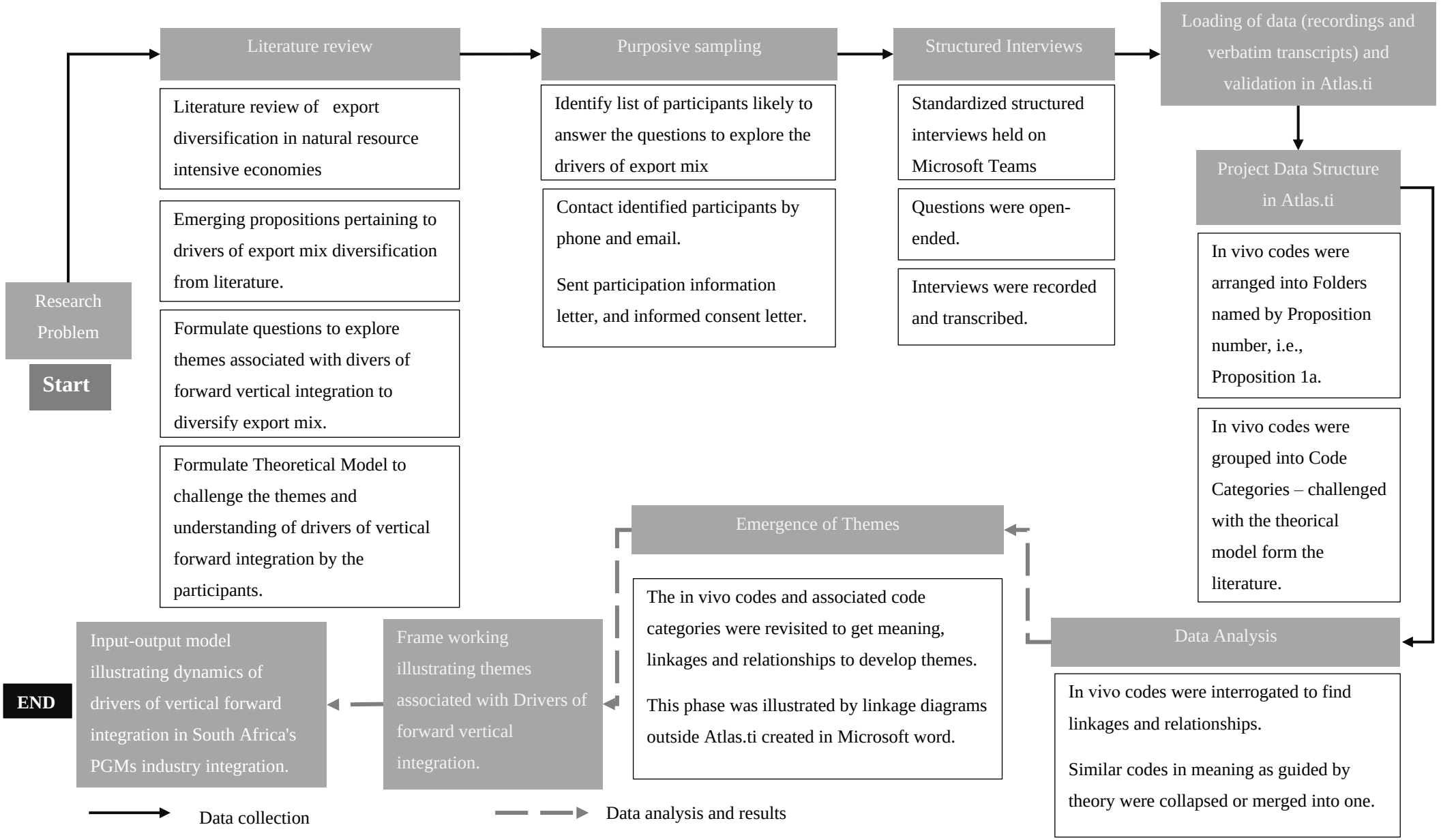

Figure 3-1. Process map illustrating procedure for data collection and analysis.

3.5 Limitations

Since this research is interpretive in nature, it is prone to bias introduced by the researcher because the researcher is part of the phenomena being researched and has preconceived ideas about the phenomena being investigated (Rehman & Alharthi, 2016). The researcher's ideas might introduce subjectivity during the coding process affecting the categories and ultimately the emerging theory (Chong & Yeo, 2015). The grounded theory is a multi-stage data analysis, an iterative and time-consuming method because of the need to cross-validate the results against the emerging theoretical framework (Harris, 2015). According to Harris (2015) and Dworkin (2012), grounded theory research design has a problem in determining the optimal sample size to reach meaningful conclusions. Most researchers use the saturation point to determine the point where the optimal sample size is achieved (Dworkin, 2012), (Harris, 2015). However, the saturation point is subjective because it is determined by the researcher's experience and other factors outside the researcher's control (Harris, 2015). Stopping data collection before reaching saturation will lead to poor quality theory (Chong & Yeo, 2015).

3.6 Evaluation of the research

Assessing the credibility of the qualitative research entails validating the appropriateness of the research design, data collection and analysis methods to the research question and paradigm including the integrity of the final results (Noble & Smith, 2015), (Leung, 2015).

According to Leung (2015), the credibility of a qualitative research can be assessed using the following criteria: (i) validity – appropriateness of the research paradigm, research design, data collection tools and process, analytical process, and emergent themes and theory to the sample and context. Noble and Smith (2015) note that validity is demonstrated by the degree to which the findings fit the data; (ii) reliability – refers to the consistent application of research methodology in data collection, analysis and decision-making allowing replicability of the results when the data is analysed by independent researcher. Noble and Smith (2015) and Leung (2015) further note that consistency and applicability must be demonstrated to prove the reliability of the final results; and (iii) Generalisability – refers to the applicability of the findings to another context (Noble & Smith, 2015). Table 3-2 below shows strategies that will be adopted to ensure the credibility of this research.

Table 3-2. Strategies to enhance the credibility of the research.

Construct	Strategies
Validity	• Identify sample layering caused by managerial levels' operations, division and corporate. • Pilot the interview to ensure that the question fits the research context and problem. • Use standardised open-ended interview question to sure context preservation. • Record the interviews. • Preserve the verbatim extracts to reduce subjectivity.
Reliability	• Document and understand own viewpoints that will introduce bias during coding. • Clear and transparent process from selection of the research paradigm, choice of research method, analytical method to selection of participants. • Peers review the emerging themes and theories with competent professional. • Use in vivo coding to remove subjectivity and preserve participant views. • Ask respondents to review the transcripts, coding, and the emergent themes – to evaluate if the results reflect their views as shared during the interview.
Generalisability	• Present an emerging theoretical framework in a diagram to illustrate the connectivity of the constructs to the dependent variable predicted by the theory.

3.7 Ethics

Harm can be done to participants during the research, therefore, the application of appropriate ethical principles is of utmost importance (Orb, Eisenhauer & Wynaden, 2001). Ethical considerations that were taken in this study were in the interest of preventing harm to the participants and in the process doing general good to the South African PGMs industry. This study is concerned with gaining an in-depth understanding of the current South African primary refined PGMs products export trade patterns and drivers that could diversify the trade mix to PGMs manufacturers. The researcher will be interviewing a layered sample from different levels of management in the Platinum mining industry. The heterogeneity of the sample introduces ethical challenges that will arise from the contrasting worldviews of the participants and that of the researcher (Chong & Yeo, 2015). Other ethical issues to consider are anonymity, confidentiality and willingness to share experiences (Sanjari, Bahramnezhad, Fomani, Shoghi, & Cheraghi, 2014). Table 3-3 below outlines measures to prevent ethical issues associated with this research.

Table 3-3. Ethical challenges facing the research and mitigation plans.

Ethical challenges	Mitigation
Different world views	The interview questions must be considerate of participants' culture, religion and perceptions about macro-environment factors affect the PGMS industry in SA. respect the participant's worldview and do not attempt to impose own worldview on the participant. The researcher must understand his own worldview to know how his subjectivity could harm the participant. Share verbatim with the participant for validation. Share the themes with the participants to avoid misrepresentation of their views
Willingness to share	A motivation letter inviting the participants for the interview. Get permission from EVP to interview participants in compliance with POPIA and protection of company information however, the researcher must approach the participants himself. Do not force the participants to take part in the study.
Anonymity	The study will not capture demographics. Pseudo-names will be used to identify participants in transcripts
Confidentiality	The participant identifier record will be kept in a password-protected folder. All information is kept in a pass-protect computer. Raw data will not be shared with people outside the study during the research process

3.8 Conclusion to Chapter 3

The grounded theory qualitative research design fits the research problem outlined in Chapter 1 because it is descriptive and inductive. The grounded theory design allowed the researcher a scope to: (i) develop an in-depth understanding of drivers of vertical forward integration; (ii) test which drivers are likely to cause diversification in SA; and (iii) to understand South African PGMs export mix through the lens of the industry players.

The purposive sampling method was used to select a sample of four senior managers in the PGMs mining sector population. Their selection was based on the following criteria: in-depth experience of PGMs macro-environment factors affecting the PGMs industry, the proximity to corporate decision-making level, their accessibility and availability, and the time limitation of the study. Data was collected by means of structured interviews held on Microsoft Teams with recorded verbatim transcripts. Each interview lasted approximately 50 minutes and was conducted in English.

Data was validated, managed, and analysed in Atlas.ti software using inductive data analysis method. In vivo coding was used to preserve what the participant said, reducing the researcher's subjectivity (Harris, 2015). The in vivo codes were collapsed into categories by looking for links and relationships leading to the emergence of themes (Harris, 2015). The process followed to analyse the data is illustrated in Figure 3-1.

Rehman and Alharthi (2016) noted that interpretive qualitative research is prone to bias introduced by the researcher because the researcher is part of the phenomena being researched and has preconceived ideas about the phenomena being investigated. Therefore the researcher's ideas might introduce subjectivity during the coding process affecting the categories and ultimately the emerging theory (Chong & Yeo, 2015). According to Haris (2015), and Chong and Yeo (2015) stopping data collection prematurely before saturation point will lead to poor quality outcomes of the study.

Measures to assess and enhance credibility of this study are tabulated in Table 3-2. Assessing the credibility of the qualitative research entails validating the appropriateness of the research design, data collection and analysis methods to the research question and paradigm including the integrity of the final results (Noble & Smith, 2015), (Leung, 2015).

Ethical considerations taken in this study in the interest of preventing harm to the participants are tabulated in Table 3-3.

Chapter 4: Presentation of Findings

This chapter presents the results of research propositions formulated in Chapter 2. Three senior managers from Platinum and Gold mining houses in South Africa were interviewed using a structured interview instrument. The participants' profiles are shown in Table 3-1 and the research instrument is shown in **Appendix B**. Research instrument

4.1 Data presentation

One-hundred and eight (108) in vivo codes were arranged in six (6) folders corresponding to the research proposition and driver of forward vertical integration, Figure 4-1. These in vivo codes were grouped into seventeen (17) code categories, Figure 4-1.

The in vivo codes are from answers given by participants pertaining to propositions in section 1.5 and associated insight-seeking questions in section 3.3. Themes emerging from code categories are presented per driver of forward vertical integration in subsequent sections 4.2 to 4.6.

A framework illustrating themes associated with drivers of forward vertical integration is presented in section 4.7 and Figure 4-2.

Participants' in vivo quotations are presented throughout the presentation of the results to remove biases and get participants' views and insights about the drivers of vertical forward integration in the South African PGMs industry.

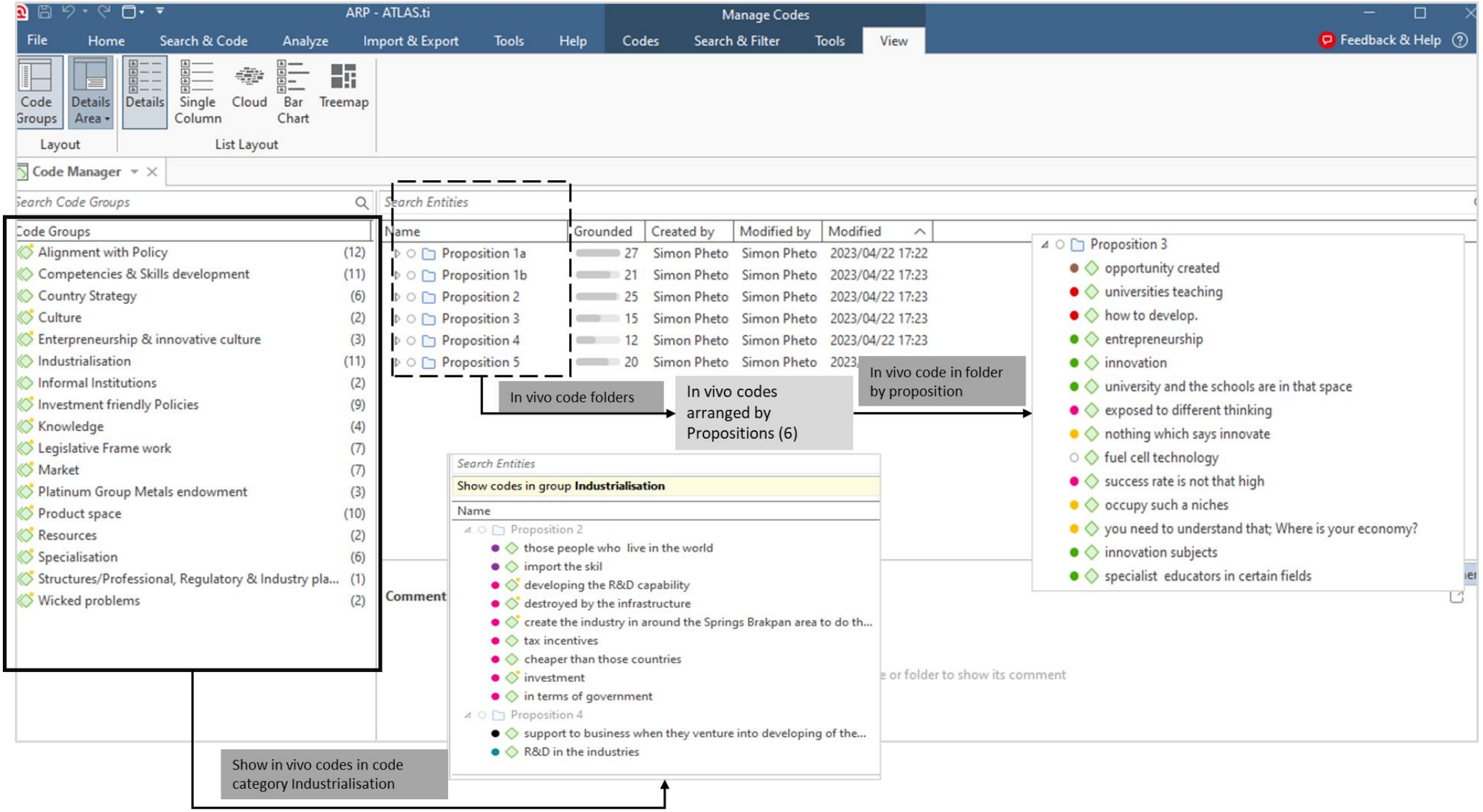

Figure 4-1. Atlas.ti screen dump illustrating arrangement of in vivo codes by proposition and groupings of in vivo codes into code categories

4.2 International Trade Theory

4.2.1 Findings pertaining to Proposition 1a: Large PGMs resources and reserves in South Africa are likely to lock South Africa in export of primary refined PGMs products.

The structured interview questions to elicit if large PGMs resources and reserves endowments in South Africa will confine the country to the export of primary refined PGMs products were:

- What do you think about the sustainability of SA's strategic position as the number one exporter of PGMs?
- Is the position good for the country?

Sixteen (16) in vivo codes were identified and grouped into three (3) code categories resulting in three (3) themes presented in Table 4-1. The participants' insights on identified code categories are summarised in Table 4-2.

The participants agree that South Africa has superior PGMs' endowments and is specialising in the primary PGMs mining value chain. There is also general agreement that the international PGMs market forces played a role in shaping the PGMs trade pattern in South Africa.

There is a consensus amongst the participants that South Africa exports the bulk of its PGMs in the form of primary refined and semi-finished PGMs-related products. The participants attribute South Africa's position as a net exporter of primary PGMs products to large PGMs resources and reserves endowments, specialisation in primary mining activities, large R&D in PGMs primary mining value chain, the historical strategic position to be known as a mining country and international PGMs market forces as indicated in Table 4-1 and Table 4-2. The participants note that the export of refined PGMs is a cheaper and quicker way for the government to earn much-needed foreign currency to mitigate wicked problems. This strategy of earning foreign currency has encouraged and cemented South Africa as a net exporter of primary refined PGMs products.

Three (3) themes, illustrated in Table 4-1, were developed from the code categories presented above. The comparative advantage theme was inferred from the code categories, PGMs endowment and specialisation in primary mining processes. South Africa's comparative advantage in the mining and export of primary PGMs is developed from its large resources and reserves and efficient mining and refining processes. South African PGMs industry developed

world-class mining and refining through years of specialisation in primary mining activities, large investments in mining-related R&D, and skills development through tertiary institutions. These institutions were often financed by mining houses.

Two themes were inferred from the *PGMs market code group*, namely, international trade agreements and liberalisation of international trade. The participants note that international trade agreements tend to discourage developing countries to manufacture finished PGMs-related products by building trade barriers such as tariffs on their imports to protect their manufacturing sectors. These developed countries also use patents to delay the diffusion of their new technologies to developing countries. The protection of intellectual property and tariffs are seen by participants as unfair international trade practices that confine developing countries like South Africa to exports of resource-intensive products.

The finding of proposition 1a is that comparative advantage in mining and the export of primary PGMs, international trade agreements favouring developed countries and non-liberalisation of international trade in the PGMs industry will lock in developing countries like South Africa in the export of resource-intensive products like primary PGMs products.

Table 4-1. Clustering of Proposition 1a codes into code categories and themes

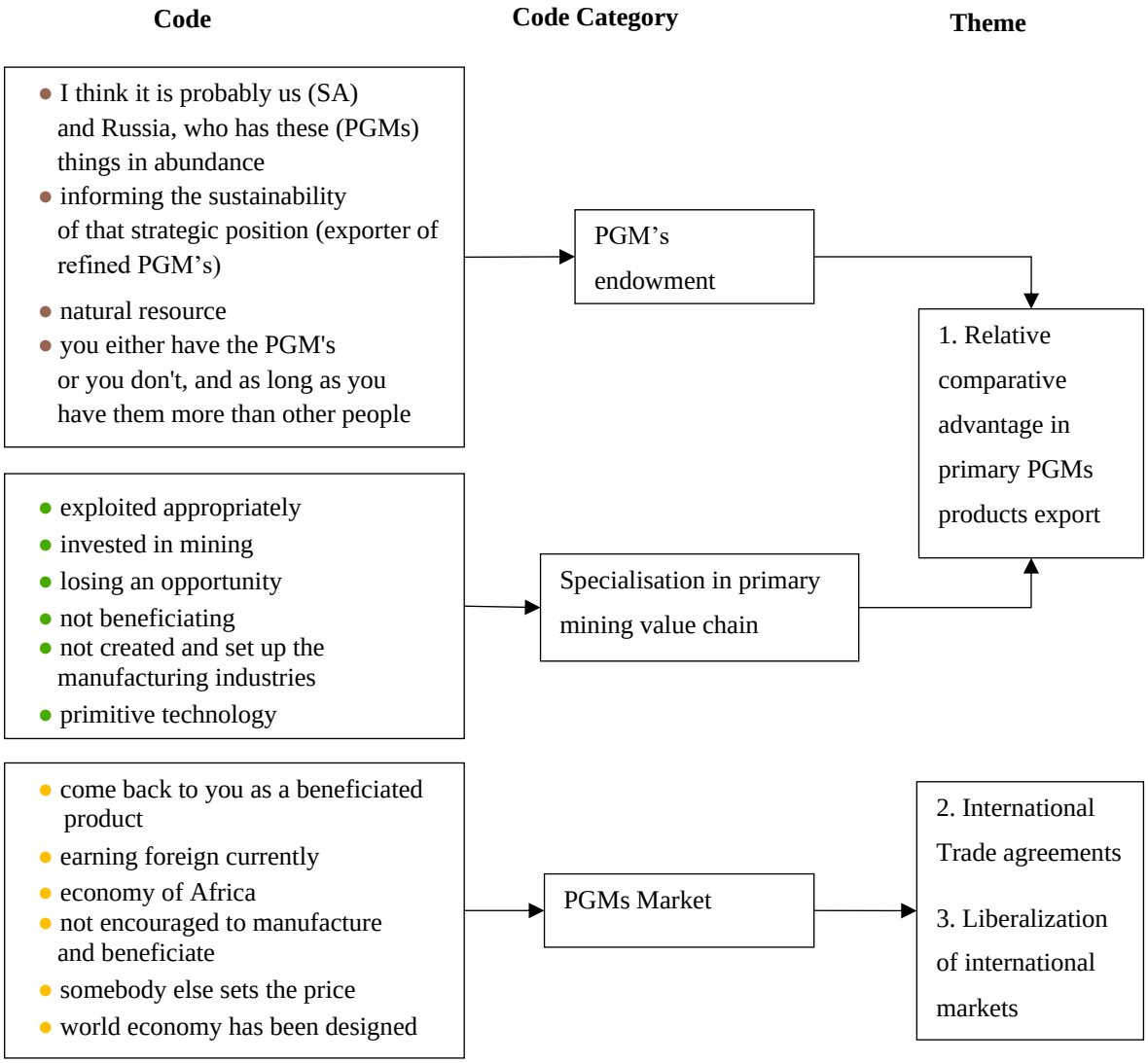

Table 4-2. Insights into emerging code categories from participants' perspective with respect to Proposition 1a

Code Group	Quotation content
PGMs endowment	*'I think it is probably us and Russia, who have these things (PGMs) in abundance. So as long as you have them, you are in a good position.'* 4:5 ¶ 8 in Participant 2_Final *'If you look at what is currently sitting with different mining companies as explored and declared resources and reserves and there's also a lot call it unexplored and undeclared, potential reserves in other parts of the country, particularly in the northern province, the eastern limb. However, those would potentially be your greenfield type of projects that can come on stream. Therefore, informing the sustainability of that strategic position for South Africa in the long term. You do also have what you would call brownfield, potential extensions, which would also inform the sustainability of the current production level in the different companies. So, there is potential from what Mother Nature has given us.*' 9:3 ¶ 39 – 40 in MBA Interview

	'We are funding a lot of mining related research.' 2:277 ¶ 122 in Participant 1_2022-12-22
	'We only invested in mining, so we are known as mining country.' 2:258 ¶ 23 in Participant 1_2022-12-22
Specialisation in primary PGMs mining process	*'Those skills have been developed. They are there and I think today those skills are in excess. Those skills were developed with the view that the future will be mining. And you know, unfortunately, that future of mining has diminish as minerals depletes.'* 4:21 ¶ 32 in Participant 2_Final
	'So, the industry has done that, but only to the extent that the skills will be mining skills, not what you can do further with minerals?"' 4:36 ¶ 33 in Participant 2_Final
	'We have resigned ourselves to being miners, with whatever primitive technology we have.' 4:14 ¶ 21 in Participant 2_Final
	'Then they will come back to you as beneficiated product and you will pay you know a higher price for that.'4:7 ¶ 12 in Participant 2_Final
	'This is good for earning foreign currency. But there you are losing the opportunity for every 4E ounce that we are exporting.' 2:256 ¶ 5 – 6 in Participant 1_2022-12-22
PGMs Market	*'World economy has been designed, that development countries will export raw materials, these raw materials will be beneficiated elsewhere to benefit, advanced economies.'* 4:6 ¶ 12 in Participant 2_Final
	'Developing countries will not be encouraged to manufacture and beneficiate and so on. You know, as a developing nation, you will be encouraged to export your products so that they are beneficiated elsewhere.' 4:13 ¶ 21 in Participant 2_Final

4.2.1.1 Summary of Proposition 1a findings: Large PGMs resources and reserves in South Africa are likely to lock South Africa in export of primary refined PGMs products.

According to the participants, large PGMs resource and reserves endowments and the decision to specialise only in primary PGMs mining activity gave South Africa a comparative advantage in the mining and export of primary PGMs' products. In the short term, this comparative advantage is giving South Africa much-needed foreign currency to mitigate its wicked problems.

Specialisation in primary PGMs mining was derived from large investments in the building of educational institutions focusing mainly on the training of professional and skilled human resources related to the primary mining value chain. Large investment in mining and refinery

processes, R&D, and the country's strategic position as a PGMs mining country also contributed to the current high levels of specialisation in the primary PGMs mining value chain.

The participants note that bilateral and multilateral trade agreements do not encourage developing countries to manufacture finished PGMs-related products. The developed countries protect their technologies with patents and their markets with tariffs making it expensive for the developing countries to compete in an open international market.

The above findings indicate that South Africa will likely remain an exporter of raw and semi-finished PGMs products due to its relative comparative advantage in PGMs export, international trade agreements and non-liberal international markets.

4.2.2 Findings pertaining to proposition 1b: Technological know-how will transform South Africa into a net exporter of finished PGMs-related products.

The research questions to determine if South Africa's technological know-how can change its export mix and if the country has the capability to continuously improve its technologies through collaborative learning, continuous knowledge creation, and the absorption of foreign knowledge in the manufacturing of PGMs-related products were:

- How would you describe South Africa's local capability to develop own technologies and absorb foreign technology?
- What is lacking for developing these capabilities?

Fifteen (15) in vivo codes were identified and grouped into three (3) code categories resulting in two (2) themes presented in Table 4-3. Participants perspective on identified code categories are summarized in

Code Group	Quotation content
Competency development and technology	*'You always develop the capacity if you need it, if you want it, you understand? So, if there's a technology that we do not have or a process that we are not familiar with to manufacture something, you can always source that, you can always, you know, learn it. So that's why I say it's more question of will and policy rather than capability. To say the reason, we are not manufacturing finished products in terms of our PGMs is because we don't know how to, I think that is not 100% true. I think it's more a question of we're not there in terms of policies or will to do it'*9:11 ¶ 109 in MBA Interview

	'We have not done it, so it's difficult to say whether, or if we have done it, perhaps not to the, you know, industrial scale, you know for export. So, in that case, not having done it is difficult to say, look. You can't judge yourself with something you have not done, but can you learn how to do it. You export technology, or rather import technology that will help you do it. You import the know how that will teach you how to do certain those things we can do.' 9:12 ¶ 111 in MBA Interview
Culture Willingness	*'I remember years ago, Harmony opened the jewellery school in Welkom, sorry, in Virginia? But it didn't work because, the willingness, the energy was not sufficient to get your jewellery making going.'* 4:10 ¶ 20 in Participant 2_Final
	'In most boards of companies, they have a CEO but in the CEO score card, it says, make as much profit as you can. There's nothing in the CEO's score card that says develop XYZ for the future.' 2:285 ¶ 297 in Participant 1_2022-12-22
	'If there's no common goal. You understand? It's just if we as the industry we want to delay things for as long as possible and stay with the things that are working for us. You know that suit us.' 4:29 ¶ 37 in Participant 2_Final
	'So, the industry developed the skills of the future employee to the extent that that employee will be involved in mining, you know, will only mine. That's the extent to which we have developed the skills. We didn't look beyond mining to downstream economies'4:20 ¶ 31 in Participant 2_Final
	'Which means that the inclination is to mine and export and not to develop people capabilities or technological capabilities to do these things (value add PGMs products).' 4:12 ¶ 20 in Participant 2_Final
Policy alignment	*"So, you require commitment and commitment comes from loyalty to the country, that we have got something to lose if things don't get better. Therefore, you commit investment. And therefore, you support policies by investing in the downstream industries'* 4:32 ¶ 140 in Participant 2_Final
	'I think Government tries to come up with a policy and there's resistance. You know, where are you going to get energy for beneficiation, you know?' 4:23 ¶ 36 in Participant 2_Final
	'But we are not funding a lot of technological related research, which we need to invest in to get to the to create the capabilities that are required.' 2:275 ¶ 124 in Participant 1_2022-12-22
	'They funded universities to keep them going to develop these skills. It was the major players. It was not necessarily government policy.' 4:17 ¶ 25 in Participant 2_Final
	'That capability was not developed over the hundred and fifty years of exploiting minerals, the people capability, technological capability was never developed because the whole point was to mine and export' 4:9 ¶ 19 in Participant 2_Final

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These questions were not fully answered by the participants because of their perspective that South Africa does not have a large PGMs-related products manufacturing sector. Participant 4 notes *'We have not done it (*manufacturing of finished PGMs-related products*), so it's difficult to say whether, or if we have done it, perhaps not at industrial scale, you know, for export. So, in that case, not having done it[sic] is difficult to say, look, you can't judge yourself with something you have not done'* 9:32 ¶ 111 in MBA Interview. Participant 2 also notes *'That capability (*manufacturing of finished PGMs-related products*) was not developed over the hundred and fifty years of exploiting minerals, the people capability, technological capability was never developed because the whole point was to mine and export'* 4:9 ¶ 19 in Participant 2_Final.

Participant 4 and others do not see the technological know-how as a limiting factor to diversifying South Africa's PGMs industry into the manufacturing sector. The consensus amongst the participants is that an outward flow of finished PGMs-related products from South Africa will occur because of policy from the government and willingness from both the government and business as indicated in Table 4-4.

The participants note that technologies can be copied, and skills can be imported through foreign direct investments if endogenic strategies are failing. In other words, policy maturity and willingness to implement policy is a precursor to enabling technological know-how to migrate the industry from a net exporter of resource intensive PGMs products to finished value add PGMs. Participant 4 summarises the consensus above as follows, *'You always develop the capacity if you need it,[sic] if you want it, you understand? So, if there's a technology that we do not have or a process that we are not familiar with to manufacture something, you[sic] can always source that, you can always, you know, learn it. So that's why I say it's more[sic] question of will and policy rather than capability. To say the reason, we are not manufacturing finished products, in terms of our PGMs is because we don't know how to, I think that is not 100% true. I think it's more a question of we're not there in terms of policies or will to do it'* 9:11 ¶ 109 in MBA Interview. In short, technological know-how is a by-product of policy from the government and willingness to act from government and business.

Participant 2 notes in the quotation, *'I think Government tries to come up with a policy and there's resistance. You know, where are you going to get energy for beneficiation, you know?'* 4:23 ¶ 36 in Participant 2_Final. According to the participants, misalignment with government policy to manufacture finished products from the vast mineral reserves endowments arises from

factors such as poor infrastructure e.g., Eskom electricity supply, CEOs not developing future skills, industry investing into maximising profits during commodity booms, little R&D investment in developing necessary skills and technologies to manufacture finished PGMs-related products, Table 4-4. Participant 1 illustrates misalignment with government policy in the quote, *'In most boards of companies, they have a CEO but in the CEO score card[sic], it says, make as much profit as you can. There's nothing in the CEO's score card[sic] that says develop XYZ for the future."* 2:285 ¶ 297 in Participant 1_2022-12-22. Participant 2 also notes misalignment in the quote, *" if there's no common goal. You[sic] understand? It's just if we[sic] as the industry we want to delay things for as long as possible and stay with[sic] the things that are working for us. You know that suit[sic] us.'* 4:29 ¶ 37 in Participant 2_Final

Sighting the Harmony Gold jewellery manufacturing initiative that failed to get off the ground and blossom, Participant 1 demonstrated that the country's culture to manufacture and willingness to engage in this sector is very crucial for South Africa to export finished PGMs-related products, Table 4-3 and Table 4-4.

The finding of proposition 1b is that policy maturity and willingness by government and business will enable technological know-how to migrate the South African PGMs industry from a net exporter of primary refined and semi-finished PGMs products to finished PGMs-related products. The technological know-how is unlocked through the following two themes namely, government policy and willingness, and clear country strategic alignment on manufacturing PGMs-related products.

Table 4-3. Clustering of Proposition 1b codes into code categories and themes

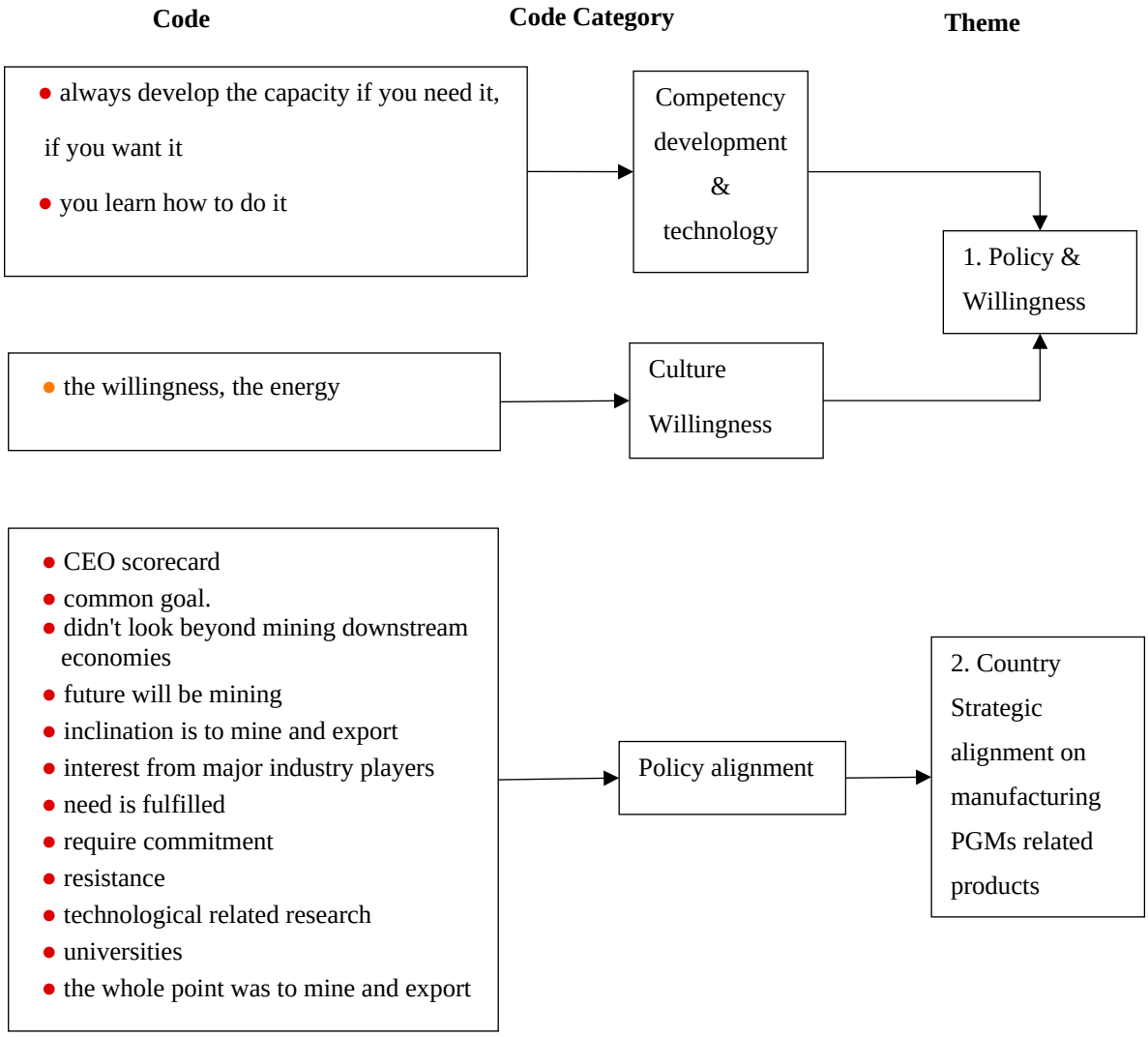

Table 4-4. Insights into emerging code categories from participants with respect to Proposition 1b

Code Group	Quotation content
Competency development and technology	*'You always develop the capacity if you need it, if you want it, you understand? So, if there's a technology that we do not have or a process that we are not familiar with to manufacture something, you can always source that, you can always, you know, learn it. So that's why I say it's more question of will and policy rather than capability. To say the reason, we are not manufacturing finished products in terms of our PGMs is because we don't know how to, I think that is not 100% true. I think it's more a question of we're not there in terms of policies or will to do it*'9:11 ¶ 109 in MBA Interview *'We have not done it, so it's difficult to say whether, or if we have done it, perhaps not to the, you know, industrial scale, you know for export. So, in that case, not having done it is difficult to say, look. You can't judge yourself with something you have not done, but can you learn how to do it. You export technology, or rather*

	import technology that will help you do it. You import the know how that will teach you how to do certain those things we can do.' 9:12 ¶ 111 in MBA Interview
Culture Willingness	*'I remember years ago, Harmony opened the jewellery school in Welkom, sorry, in Virginia? But it didn't work because, the willingness, the energy was not sufficient to get your jewellery making going.'* 4:10 ¶ 20 in Participant 2_Final
Policy alignment	*'In most boards of companies, they have a CEO but in the CEO score card, it says, make as much profit as you can. There's nothing in the CEO's score card that says develop XYZ for the future.'* 2:285 ¶ 297 in Participant 1_2022-12-22 *'If there's no common goal. You understand? It's just if we as the industry we want to delay things for as long as possible and stay with the things that are working for us. You know that suit us.'* 4:29 ¶ 37 in Participant 2_Final *'So, the industry developed the skills of the future employee to the extent that that employee will be involved in mining, you know, will only mine. That's the extent to which we have developed the skills. We didn't look beyond mining to downstream economies*'4:20 ¶ 31 in Participant 2_Final *'Which means that the inclination is to mine and export and not to develop people capabilities or technological capabilities to do these things (value add PGMs products).'* 4:12 ¶ 20 in Participant 2_Final *"So, you require commitment and commitment comes from loyalty to the country, that we have got something to lose if things don't get better. Therefore, you commit investment. And therefore, you support policies by investing in the downstream industries'* 4:32 ¶ 140 in Participant 2_Final *'I think Government tries to come up with a policy and there's resistance. You know, where are you going to get energy for beneficiation, you know?'* 4:23 ¶ 36 in Participant 2_Final *'But we are not funding a lot of technological related research, which we need to invest in to get to the to create the capabilities that are required.'* 2:275 ¶ 124 in Participant 1_2022-12-22 *'They funded universities to keep them going to develop these skills. It was the major players. It was not necessarily government policy.'* 4:17 ¶ 25 in Participant 2_Final *'That capability was not developed over the hundred and fifty years of exploiting minerals, the people capability, technological capability was never developed because the whole point was to mine and export'* 4:9 ¶ 19 in Participant 2_Final

4.2.2.1 Summary of Proposition 1b findings: Technological know-how will transform South Africa into a net exporter of finished PGMs-related products.

The participants did not fully answer the research question related to Proposition 1b because South Africa is not manufacturing finished PGMs-related products at an industrial scale. Participant 4 disagrees with Proposition 1b that South Africa is unable to manufacture finished PGMs-related products because of a lack of technological know-how. The participants are of the view that progressive policies from the government and willingness from both the government and business are crucial to position South Africa as a net exporter of finished PGMs-related products. According to the participants' progressive policies and willingness to implement policies will result in skills development through FDI, vocational training and immigration of skilled human resources. The participants note that technologies can be copied from foreign players or brought into the country by multinational organisations through FDI policy. The participants see the lack of progressive policies from the government and unwillingness by both the government and business are as limiting factors to change South Africa's trade pattern in PGMs. Technological know-how is a product of progressive policy from the government and willingness from both the government and business. Society and the industry players' culture to manufacture and willingness to play in the PGMs-related products manufacturing sector is noted by the participants as another important factor to change South Africa's trade pattern in PGMs.

Although the South African government has established some policies to encourage the manufacturing of PGMs-related products, the participants note that there are major misalignments between the industry players and the government. These policy misalignments resulted in policy failure and the SA PGMs industry participating largely in the export of raw PGMs products. Policy misalignments are caused by factors such as poor infrastructure delivery by the government such as ESKOM power failures, industry developing primarily mining-related skills and technology to satisfy their needs, low expenditure on R&D by government and industry to develop and expand PGMs-related products manufacturing sector capabilities.

The theme emerging from Proposal 1b is that the government must have progressive policies and the willingness for South Africa to acquire the necessary skills and technology to diversify the PGMs sector. The second theme emerging is that the country needs to have a clear strategic

position and alignment or buy-in of society and business with respect to being an exporter of finished PGMs-related products.

According to the participants, progressive policy and willingness from the government will enable South Africa to source the required technological know-how through the copying of foreign technology and FDI to transform South African trade patterns from net exporter of primary PGMs products to net exporter of finished PGMs-related products.

4.3 Institutional regime

4.3.1 Findings pertaining to Proposition 2: Progressive policies implemented by the formal institutions will cause gradual diversification of South Africa's PGMs industry into a net exporter of finished PGMs-related products.

The research questions to probe if South Africa's government and business institutions will be able to work together to adopt policies that can cause gradual diversification of South Africa's PGMs industry into a net exporter of finished PGMs-related products were:

- What is the role of government institutions in diversifying PGMs industry?
- How do you feel about the role of business institutions in the SA PGMs sector?

Thirteen (13) in vivo codes were identified and grouped into four (4) code categories resulting in six (6) themes presented in Table 4-5. The participants' perspectives on identified code categories are summarised in Table 4-6.

The participants agree that the role of government includes, amongst others, the responsibility to define the country's strategic intent in terms of PGMs trade. The responsibility also extends to creating and implementing policies, systems, and structures to position South Africa as a finished PGMs product exporter. Participant 4 illustrates the above consensus as follows; *'...as I have mentioned to you, is to create policy that supports beneficiation and also position the country as a finished product exporter. Secondly[sic] is to put in place systems and also creating environment[sic] that would support investments into beneficiation and manufacturing with respect to PGMs – related[sic] end product'* 9:14 ¶ 125 – 126 in MBA Interview. The participants see the role of business as a catalyst to lobby for investment and industrialisation-friendly policies that focus on manufacturing in the PGMs industry. The business sector has the responsibility to raise capital to exploit opportunities created by policy for sustainable economic gain. Participant 4 notes `*...So that is, the role of business is to identify*

those opportunities (manufacturing of finished PGMs-related products) *and lobby for capital, you know and invest in the know-how in terms of processes.'* 9:17 ¶ 150 in MBA Interview.

Insights from the participants identified four code categories explaining the impact and roles of formal and informal institutions to diversify the South African PGMs industry. Those four code categories are, lobbying by informal institutions, industrialisation, legislative framework, and regulatory bodies summarised in Table 4-5 and Table 4-6.

According to the participants, the South African government must adopt industrialisation policies focusing on the manufacturing sector of the PGMs industry. The policies include, and are not limited to, tax incentives to encourage R&D and manufacturing. The participants also note that special servitudes for the PGMs manufacturing sector land use will reduce barriers to entry and encourage participation by the business sector. The participants note that tax credits in the sector will enable local PGMs product manufacturers to be competitive. According to the participants, the provision and maintenance of world-class infrastructure like a stable electricity grid is key for the success of the manufacturing sector in South Africa's PGMs industry. Participant 1 gave an example of a dairy company in the Northwest Province that moved from Brits to Durban in Kwazulu-Natal province because of poor infrastructure and services resulting in the collapse of the dairy industry in the province. In a quote, Participant 1 says *'... some of the industries we have,[sic] are destroyed by our infrastructure, is exactly[sic] the same thing as that company (Clover) that was here in Northwest, and they were saying nothing works here? we go down to Durban because things are little[sic] bit better there.'* 2:283 ¶ 266 – 268 in Participant 1_2022-12-22.

The participants suggest the provision of immigration policies that allow the inflow of highly skilled immigrants to close the human resource gap to enable manufacturing in the PGMs sector.

The participants suggest that the minerals and mining policy must be revised to include participation in PGMs' downstream activities. Participant 1 says the following about the legislative framework to support manufacturing in the PGMs sector, *'If you want to go that route (manufacturing of PGMs products) where you develop downstream.[sic] You should have put that benchmark as part of the mining license requirement. To say I'm giving you this PGM mining license.[sic] However, you must invest so much money to make sure that your employees,[sic] have the future required skills. So, you must upgrade their skills. You have to invest in R&D'* 2:286 ¶ 303 – 304 in Participant 1_2022-12-22. According to the participants,

the minerals and mining legislative framework should prescribe R&D and participation in the PGMs manufacturing sector and provide objective quantitative measures of the country's intent. The minerals and mining legislative framework should demonstrate the country's strategic intent to manufacture finished PGMs-related products.

The participants expressed the need for, and empowerment of a special scientific regulatory body to ensure the delivery of the strategic intent to manufacture finished PGMs-related products. They suggested that the regulatory body must encourage and lobby funding for R&D, skills development, lobby foreign investments, measure the performance of skills development institutions, and continuously review the policies to expand the PGMs manufacturing sectors.

The code categories presented in Table 4-5. Clustering of Proposition 2 codes into code categories and themes, were clustered into six themes namely: ability to raise capital, fiscal policy, industrial policies, high skills immigration policy, minerals and mining policy, and science and innovation policy.

Therefore, the finding of Proposition 2 is that South Africa will develop a comparative advantage in the export of finished PGMs-related products if it is enabled by the government industrial policies such as reducing total production costs by cutting taxes, subsidies to reduce the impact of tariffs imposed by developed countries, special rates for PGMs manufacturing sector land use, increasing public funds spending on R&D, attracting foreign talent, cheap electricity, and world- class infrastructure.

Table 4-5. Clustering of Proposition 2 codes into code categories and themes

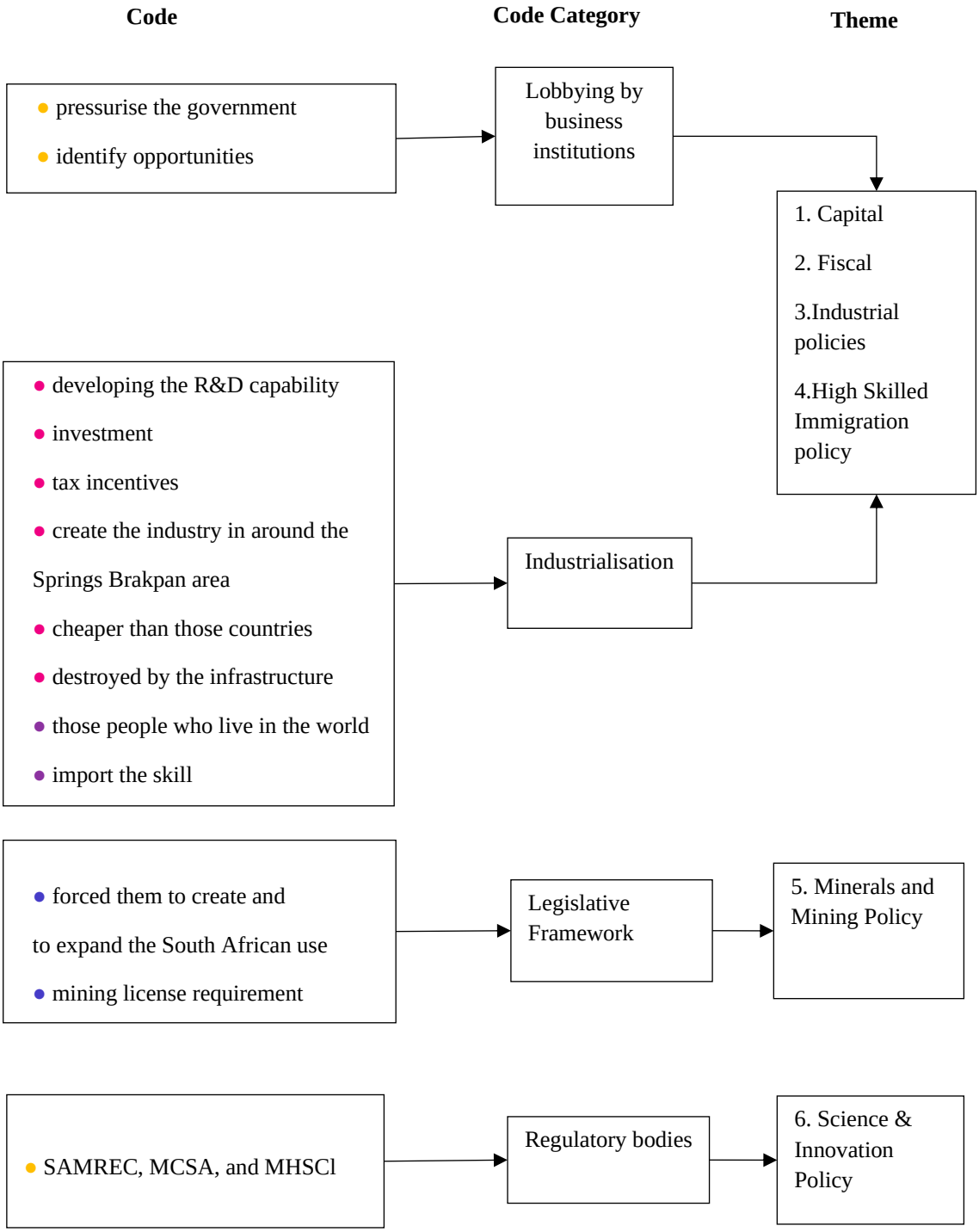

Table 4-6. Insights into emerging code categories from participants with respect to Proposition 2

Code Group	Quotation content
Legislative framework	*'If you want to go that route (manufacturing of PGMs products) where you develop downstream. You should have put that benchmark as part of the mining license requirement. To say I'm giving you this PGM mining license. However, you must invest so much money to make sure that your employees have the future required skills. So, you must upgrade their skills. You have to invest in R&D'* 2:286 ¶ 303 – 304 in Participant 1_2022-12-22
Business Institutions lobbying	*'Yeah, look, the private sector cannot you know put the policy in place. That is a government's job, but they can lobby the government; they can pressurize the government.'* 9:16 ¶ 140 – 141 in MBA Interview *'So that is the role of business to identify those opportunities and lobby for capital, you know and invest in the know how in terms of processes.'* 9:17 ¶ 150 in MBA Interview *'there's a lot of upfront investment that we have to make together. So, South Africa government and companies have to work together'* 2:268 ¶ 96 – 98 in Participant 1_2022-12-22
Industrialisation	*'Give the tax incentives from R&D point of view, from investment in this space. Then we'll actually be cheaper than those countries because those countries have to now transport the platinum there and then bring it back to us as something else later on.'* 2:303 ¶ 242 in Participant 1_2022-12-22 *'there's a lot of upfront investment that we have to make together. So, South Africa government and companies'* 2:268 ¶ 96 – 98 in Participant 1_2022-12-22 *'The universities also have a part to play, where they can actually bring in the research the companies can fund the research, but the universities can execute that research. We are funding a lot of mining related research.'* 2:276 ¶ 122 in Participant 1_2022-12-22 *'However, you could actually create the industry in around the Springs Brakpan area to do that work. Even Johnson Matthew, I think it's in Germiston. They are all together there. So, we must obviously look in those space. But government must lead the way. Let me put it that way'* 2:284 ¶ 280 – 281 in Participant 1_2022-12-22 *'Where are you going to get energy for beneficiation, you know? Where will you get electricity? There is not enough electricity for this, and for that and for that'* 4:24 ¶ 36 in Participant 2_Final *'You can always import the skill. You can always get people who are in those first world countries to come in. But surely you cannot have that ability, if you cannot keep the lights on, the whole debate becomes a nonstarter for me.'* 2:273 ¶ 121 in Participant 1_2022-12-22

Regulatory body	*'Just like we've set up SAMREC, DMRE helping to improve safety, you could set up the same thing but now to look at downstream work of the PGM's, but you're going to have to be basically intentional. It's already happening, by the way.'* 2:279 ¶ 186 in Participant 1_2022-12-22

4.3.2 Summary of Proposition 2 findings: Progressive policies implemented by the formal institutions will cause gradual diversification of South Africa's PGMs industry into a net exporter of finished PGMs-related products.

The participants noted a clear distinction between the role of government and business institutions pertaining to the gradual diversification of the PGMs industry from a net exporter of primary PGMs products to a net exporter of finished PGMs-related products. The government's role is to position South Africa as a finished PGMs-related products exporter by defining the country's strategic intent. The government's role extends to creating and implementing policies, systems, and structures to support the PGMs manufacturing sector. The business institution's role is to lobby the government to implement investment-friendly policies and to exploit opportunities created by those policies for sustainable economic gains.

The participants suggest that South Africa can develop a comparative advantage in the export of finished PGMs products through policies that encourage the manufacturing of finished PGMs-related products such as:

1. Fiscal policy - spending on R&D and skills development
2. Industrial policy – special servitudes for the PGMs manufacturing sector land use, tax credits for R&D, tax credits for future skills development, functional infrastructure
3. High Skilled Immigration policy – attract talent for PGMs manufacturing.
4. Science and innovation policy – PGMs manufacturing regulatory body.
5. Minerals and mining policy – a legislative framework to tie mining license to downstream activities such as manufacturing and R&D

4.4 Innovative capabilities

4.4.1 Findings pertaining to Proposition 3: Education and innovation strategies in South Africa will likely create diversification of South African PGMs industry.

The research questions to probe if South Africa's education and innovation strategies will be able to develop the human resource capital and technology required to gradually diversify the PGMs mining sector into a PGMs-related products manufacturing sector were:

- What are your feelings about South Africa's education and innovation strategies to build innovative capabilities?
- What can be done to improve impact of these strategies to diversify PGMs industry?

Thirteen (13) in vivo codes were identified and grouped into three (3) code categories resulting in two (2) themes presented in Table 4-7. The participants' perspectives on identified code categories are summarised in Table 4-8.

The participants' views are that South Africa does not have entrenched education and innovation strategies. The in vivo codes were clustered into three code categories namely, skills development, culture, and country strategy. The code in the code category, skills development, outlines various education and innovation strategies to develop capable human resources and technologies to industrialise the PGMs mining sector of South Africa. According to the participants, skills development must be built upon the assessment of the country's trade mix, needs, comparative advantage, and a good understanding of what drives the local economy as illustrated by Participant 2 in the quote, *'you need to understand that,[sic] where is your economy? What should drive the economy and therefore[sic] what skills should match that economy?'* 4:31 ¶ 88 in Participant 2_Final.

The consensus amongst the participants is that innovation curriculum and entrepreneurship must be introduced earlier in the lower level of education to develop and establish an innovative culture and human capital's ability to engage in the economic exploitation of new or existing PGMs-related products. To support the development of innovative skills and entrepreneurship, the participants noted the need to build educational institutions that specialise only in technology as illustrated by Participant 1 in the quote, *'To have that impact, but to also not necessarily from BEE point of view, can we make sure that the university and the schools are in that space, are operating at that level, other, countries have lot[sic] of technological[sic] universities. University,[sic] which are not teaching the normal curriculum anymore. Yeah,*

only focusing on technology.' 2:293 ¶ 381 in Participant 1_2022-12-22. These educational institutions must be resourced with specialist educators to develop a deep understanding of subject matter from the lower levels as noted by Participant 4 in Table 4-8.

According to Participant 1, the difference between South Africa and other industrialised countries like the United States is that those countries have a different way of thinking in terms of innovation and entrepreneurship which they have developed into the national and corporate culture. In other words, the informal and formal institutions in South Africa, and the communities they serve must have the willingness to develop and acquire knowledge and new technology necessary to participate in and transform the current PGMs trade patterns in the country. The participants noted that the strategic intent to manufacture finished PGMs-related products must be clearly articulated in the national strategy. A clear strategic intent to manufacture will guide the necessary education and innovative strategies fit to develop adaptive human resources and technology to compete in the export of finished PGMs-related products.

Two (2) themes emerged from the three code categories presented by the participants in Proposition 3 namely: the education policy, and science and innovation policy. The participants' insights with respect to education policy are summarised below.

1. Education objectives – must develop professional and skilled human capital to support the finished PGMs products manufacturing.
2. Educational institution architecture – must build and resource institutions of technology to develop human resources and technology to support a competitive PGMs manufacturing sector.
3. Specialisation in education - subject matter experts in mathematics and science, introduction of innovation and entrepreneurship subject content earlier in learners' development. The participants see this as a key to developing a national innovation and entrepreneurship culture.

The participants note that science & innovation policy must ensure that players in the mining industry spend money on downstream innovation. The corporate innovation culture in South Africa is almost not existent, as noted by Participant 1 in the quote, *'I've been in PGMs for the past 20 years. We have not looked at that space, so if you look at the CEOs, even general managers.[sic] There's nothing which says innovate[sic] (in their KPA)[sic]. Can we do things differently? What technology exists? Uh, can we visit this country and go and see what works*

there?' 2:295 ¶ 413 – 416 in Participant 1_2022-12-22. Therefore, science and innovation policy supported by a legislative framework should be put in place to encourage a corporate innovation culture.

The science and innovation policy must also be geared towards creating an innovation and entrepreneurship culture in the communities and local businesses. According to the participants entrepreneurship and innovation culture is a differential between developed and developing countries, and key in developing an economy based on manufacturing of finished PGMs-related products.

The finding of Proposition 3 is that education and innovation strategies do not exist or are still in the early implementation phases, however, rapid introduction and early implementation will result in the diversification of the PGMs mining sector into a finished PGMs-related products manufacturing sector.

Table 4-7. Clustering of Proposition 3 codes into code categories and themes

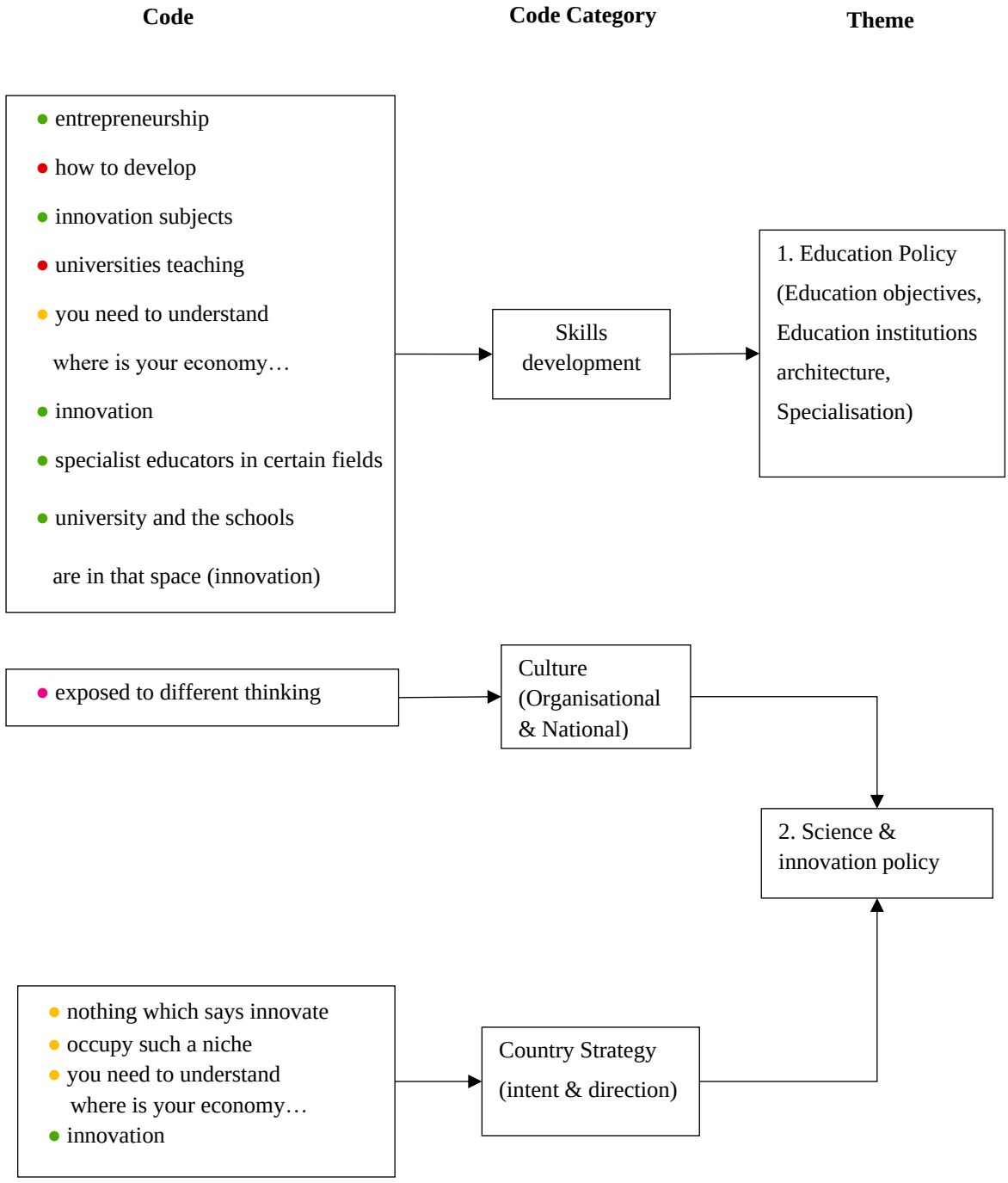

Table 4-8. Insights into emerging code categories from participants with respect to Proposition 3

Code Group	Quotation content
Skills development	*'If you look at the skills that are being trained at universities, you are trained how to fix something, how to fix a car. But we are not necessarily trained how to develop (to manufacture and innovate).'* 2:288 ¶ 351 in Participant 1_2022-12-22 *'We are being taught to regurgitate the knowledge that was created in the past. We're not really making ground-breaking stuff"'* 2:267 ¶ 89 in Participant 1_2022-12-22 *'You need to understand that, where is your economy? What should drive the economy and therefore what skills should match that economy?'* 4:31 ¶ 88 in Participant 2_Final *'You look at our skills at our universities, entrepreneurship has not really been taught for the lower level. It gets it gets taught right at the varsity level. But you needed entrepreneurship developed, I think, at the primary level at the primary school level. So, it has to be encouraged.'* 2:291 ¶ 359 – 360 in Participant 1_2022-12-22 *'Even though they might have introduced innovation subjects, I do think that our education system is not positioned to induce that innovative mindset because from early age is still much generalized. If you look at the content, we need to move to a stage whereby at an early age of your school career, if you more into math and science, then focus on that and leave everything else that has to do with history as an example. because then you can spend more time in that.'* 9:19 ¶ 163 in MBA Interview *'Apply your mind in terms of understanding how it works and how else can it work in terms of improvement. And that's where the innovation comes in and that's what I feel we possibly need to position South Africa's education system for. Is also an element, not just on what the education system is, but you know, do we have specialist educators in certain fields, you know, because as I said, it's much more generalized. So do you have specialist, you know, as an example math and science teachers who really specialize in that, they understand the content very well, such that they can impart, the knowledge to the youngsters.'* 9:20 ¶ 163 in MBA Interview *'To have that impact, but to also not necessarily from BEE point of view, can we make sure that the university and the schools are in that space, are operating at that level, there's a lot of other, countries have lot of technological universities. University, which are not teaching the normal curriculum anymore. Yeah, only focusing on technology.'* 2:293 ¶ 381 in Participant 1_2022-12-22
Culture	*'In the US compared to South Africa, you also get to exposed to different thinking and that for me is key. Which we do not have currently in South Africa. But is it something that other industries that have developed it very well by the way, industries which have invested in innovation.'* 2:294 ¶ 406 in Participant 1_2022-12-22
Science & Innovation policy	*'I've been in PGMs for the past 20 years. We have not looked at that space, so if you look at the CEOs, even general managers. There's nothing which says innovate (in*

> *their KPA). Can we do things differently? What technology exist? Uh, can we visit this country and go and see what works there?'* 2:295 ¶ 413 – 416 in Participant 1_2022-12-22
>
> *'Innovation does not exist, there is no curriculum which talks about innovation. It might talk about computer science and technology. But is not really drilled into us and same as the issue of investing social capital into developing these industries. You almost going to have to force companies to invest in that space and to have a clear plan of what are they are doing. And you measure the companies easier to say we have invested so much in that space, then you'll be in a better position. Let me put it that way.'* 2:292 ¶ 371 – 373 in Participant 1_2022-12-22

4.4.2 Summary of Proposition 3 findings: Education and innovation strategies in South Africa will likely create diversification of South African PGMs industry.

The consensus amongst the participants is that education and innovation strategies to develop human capital and technology to support the transformation of the South African economy into a net exporter of finished PGMs products do not exist. There is the late introduction of innovation and entrepreneurship curricula in South African educational institutions to develop human resource capital that can create new knowledge and technology and absorb existing foreign technology.

According to the participants, education and innovative strategies must be guided by the current state of the economy, the factors of production driving the economy and the skills required to match the economy and the projected path of economic transformation. Code categories emerging from Proposition 3 are skills development, culture, and national strategy. Skills development must be geared towards creating and supporting professionals and skilled labour capable of creating knowledge and monetising copied foreign technologies in the PGMs manufacturing sector. According to the participants, national and organisational culture with respect to innovation and entrepreneurship is a determinant of the human resource capital potential to innovate. The participants agree that developed countries are exporting finished PGMs products because their populations and business sectors have been successful in building innovative and entrepreneurship cultures.

Although South Africa's education and innovation strategies are non-existent or are still in the early implementation phases, the rapid introduction and early implementation of these strategies will result in the diversification of the PGMs mining sector into a finished PGMs-related products manufacturing sector. The themes emerging from the participants pertaining

to effective education and innovative strategies are education policy, and science and innovation policy.

4.5 Relatedness of capabilities

4.5.1 Findings pertaining to Proposition 4: South Africa's PGMs product space network density is likely to sustain diversification and expansion of current PGMs-related products.

The research questions to probe if South Africa's existing human resource capabilities, technology, locally PGMs-related products and supporting value chain, and institutions can be rearranged to gradually diversify the PGMs mining sector into a PGMs manufacturing sector were:

- What is your view about the relationship of products manufactured in South Africa and its PGMs endowment?
- What is required to increase the relatedness of capabilities in the South African PGMs value chain?

Twelve (12) in vivo codes were identified and grouped into three (3) code categories resulting in four (4) themes presented in Table 4-9. The participants' perspectives on identified code categories are summarised in Table 4-10.

The participants agree that the relationship between locally manufactured finished PGMs products and the raw PGMs exports is negative as noted by Participant 4 in the quotation,

'*…and manufacturing in SA that is related to the amount[sic] of PGMs that we actually[sic] exporting, so in essence, I think we use less of our PGM's[sic] for manufacturing locally than what we export.' 9:32 ¶ 189 – 190 in MBA Interview.*

Three code categories emerged from the in vivo codes namely: skill, government intervention and the PGMs manufacturing sector. In terms of code group skills, the participants highlight that South Africa has not intentionally developed skills for participants downstream of the PGMs value chain. South Africa has excess skills upstream of the PGMs value chain and a deficit in downstream activities. As a result, the participants feel that South Africa does not have a strong and diverse human resource capability to expand and increase the range of current PGMs-related products, Table 4-9 and Table 4-10.

However, government interventions such as supporting businesses in terms of R&D, tax rebates, and assisting with lobbying and raising capital for manufacturing, will enhance South Africa's human resources and technological capabilities development, Table 4-9. The participants note that there are examples of R&D driven by local mining companies such as hydrogen-powered trucks at Mogalakwena, Sibanye-Stillwater, BASF & Impala tri-metal catalytic converter for the light-duty gasoline vehicles project. These R&D initiatives could be a lot more impactful and make significant transformations to South Africa's economic structure if they were proactively influenced and supported by the government in terms of policy and legislative framework as indicated in Table 4-10. Participant 4 notes that an investment-friendly environment such as a government tax regime to spur manufacturing, lobbying for inward foreign investment capital, clarity in terms of regulation and political stability are required to build and expand capabilities in the existing PGMs-related product space.

A third code group category from the participants is South Africa's PGMs manufacturing sector. The South African PGMs manufacturing sector exists, however, it is small as indicated by Participant 4, *'As I said, this is my sense I don't have data to back it up, probably export more than 90% of our PGM's and use probably 10% or less[sic] with respect to local manufacturing…'* 9:28 ¶ 195 in MBA Interview. The participants note that South Africa is home to leading world companies in chemistry such as BASF and Johnson Matthey, however, these companies have a small footprint in South Africa and are exporting PGMs semi-finished products to developed countries. This cripples South Africa's ability to increase the density of finished PGMs products produced locally. South Africa has a growing automotive assembly industry giving the country the scope to expand the range of PGMs-related products. However, for this to happen the government must encourage the automobile assembly industry to branch into manufacturing components locally through investment-friendly policy and legislation as indicated in **Error! Reference source not found.**Table 4-10.

The participants feel that the PGMs product space in South Africa is fragmented and will require intentional investment in the entire supply chain due to deindustrialisation. Participant 1's views about the PGMs products space are as follows, *'We have to import things like steel. We used to have companies like Highveld Steel, Iscor in South Africa, making our own steel, and now you must import those things, although you want to create the industry, we must import a lot of things. So, you're going to have to actually look at the whole value chain.'* 2:316 ¶ 145 in Participant 1_2022-12-22. Therefore, economic structural problems in South Africa

such as deindustrialisation, impede the expansion of the PGMs manufacturing sector due to supply chain barriers shown in Table 4-10.

Four (4) themes emerging from the code categories presented above are human resource capabilities, industrial policy, legislative framework and the PGMs product space.

Foreign multinationals already participating in South Africa's PGMs-related products manufacturing sector such as BASF and Johnson Matthey offer an opportunity to train and rearrange the current skills to fit South Africa's intent to diversify and expand the existing PGMs product. In short, the companies and the government must actively develop new skills to correct the skill imbalance and tip it towards manufacturing PGMs-related products.

The industrial policy encouraging manufacturing such as the highly skilled immigration policy, fiscal policy in terms of taxation and R&D, foreign investment policy, special economic zones, and science and innovation policy exist but need enthusiastic implementation and measuring through the legislative framework. The theme legislative framework arises from the codes, *'nothing happens in industries until you force'* and code group *government interventions"'*. The government must re-arrange the existing mineral and mining policy to fit South Africa's strategic intent to expand and diversify the local PGMs-related product range and be a net exporter of finished PGMs-related products.

The theme PGMs product space comes from the code category 'South Africa's PGMs manufacturing sector.' The insights brought out by this theme are that South Africa's PGMs manufacturing sector is small less dense, and mostly exports semi-finished products. This theme highlights South Africa's de-industrialisation problem. The de-industrialisation of the South African economy contributes to the fragmentation and de-densification of the PGMs manufacturing sector.

Although South Africa's product space network is less dense, Proposition 4 findings show that there is enough skills and technology intensity in the South African PGMs product space to sustain the forward vertical integration and expansion of current PGMs-related products.

Table 4-9. Clustering of proposition 4 codes into code categories and themes

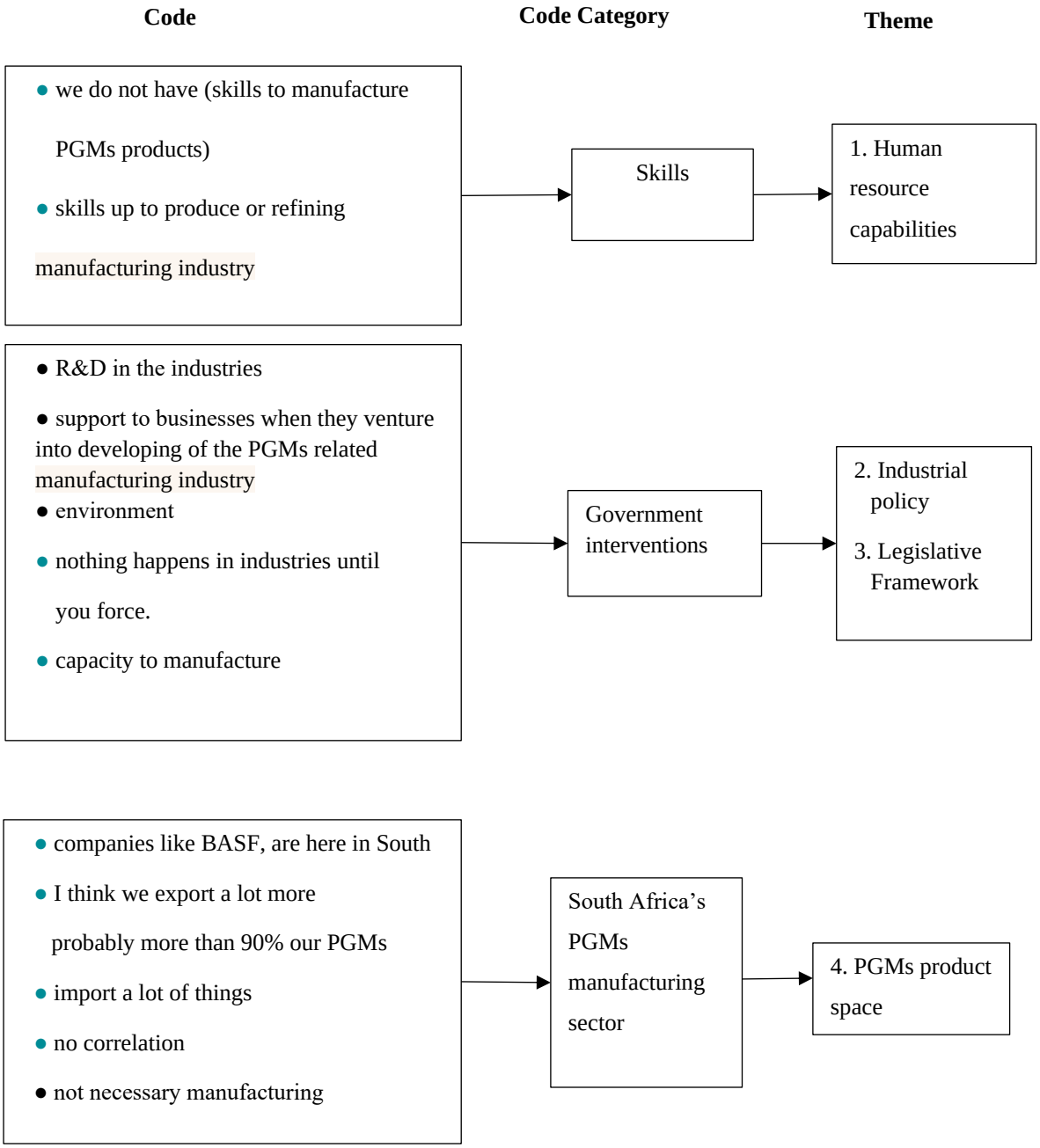

Table 4-10. Insights into emerging code categories from participants with respect to Proposition 4

Code Group	Quotation content
Skills development	*'However, the skills to take that same PGM and make catalytic converters out of it and make all the jewellery and other things, we do not have. We have not really embarked on it, but is it a skill which we could create? We can. It's going to cost us a lot of initial investment up front. However, if government for example assist in terms of developing the R&D capability and also create grants where companies can get tax rebates if they invest in our R&D which is, actually a program that we have in this country.*' 2:318 ¶ 169 in Participant 1_2022-12-22 *'However, on the PGM site we have these skills up to a certain level. So, we have the skills to produce or refine the final product. Which is refined PGMs.'* 2:317 ¶ 168 – 169 in Participant 1_2022-12-22
Government interventions	*'Support to business when they venture into developing of the PGM related manufacturing industry, there needs to be lobbying of capital to come into the country.'* 9:31 ¶ 207 – 208 in MBA Interview *'If even as you said the universities, those type of things and there are R&D in the industries, just like we've set up SAMREC, DMRE helping to improve safety, you could set up the same thing but now to look at downstream work of the PGM's, but you're going to have to be intentional. It's already happening, by the way. If you look at, for example that truck powered truck at Mogalakwena; Sibanye-Stillwater, BASF & Impala tri-metal catalytic converter for light duty gasoline vehicles project.* 2:319 ¶ 184 in Participant 1_2022-12-22 *'Environment in terms of policy in terms of tax, in terms of, you know, political stability, charity in terms of regulation and all of those things, that's what's needed to be put in place to support development of that manufacturing in the PGM related industry.*'9:34 ¶ 204 – 205 in MBA Interview *'At first I thought industries will do these things by themselves as I get older and older, I'm realizing nothing happens in industries until you force it'* 2:314 ¶ 508 in Participant 1_2022-12-22 *'Policy to support that from government, creation of environment that would attract investment into building that capacity to manufacture locally.'* 9:33 ¶ 204 in MBA Interview
South Africa's PGMs manufacturing	*'To actually achieve what needs to be achieved, but in terms of. Can you copy the technology that already exist? You can; you have companies like BASF, a German company is here in South Africa making catalytic converters? You have companies like Johnson Matthey here in South Africa making a specializing in PGMS chemistry and platinum other PGM products. However, they are also taking the unfinished platinum products outside the country. The base of both Johnson Matthey is still UK.'* 2:315 ¶ 104 – 105 in Participant 1_2022-12-22

> *'….. and manufacturing in SA that is related to the amount of PGMs that we actually exporting, so in essence, I think we use less of our PGM's for manufacturing locally than what we export.* 9:32 ¶ 189 – 190 in MBA Interview
>
> *'We have to import things like steel. We used to have companies like Highveld Steel, Iscor in South Africa, making our own steel, and now you must import those things, although you want to create the industry, but we must import a lot of things. So, you're going to have to actually look at the whole value chain.'* 2:316 ¶ 145 in Participant 1_2022-12-22
>
> *'We not necessary manufacturing those are Amaroks and those Mercedes Benz, we are assembling them. That's for me, is what the problem is. I would like us not to assemble them but create certain components and we can then ship these components to everywhere in the world. But if they created by us will be better positioned.'* 2:313 ¶ 703 in Participant 1_2022-12-22

4.5.2 Summary of Proposition 4 findings: South Africa's PGMs product space network density is likely to sustain diversification and expansion of current PGMs-related products.

Although with a small footprint, South Africa has one of the world's largest companies manufacturing a wide range of chemicals, for example, BASF and a major player in PGMs chemistry, Johnson Matthey, which plays an important role in the local PGMs-related products manufacturing sector. The participants note that South Africa has a growing automotive assembly industry which through investment could add to the PGMs product space by locally manufacturing electronic components and other parts. The participants feel that the local PGMs products space is fragmented because the country exports more semi-finished PGMs products and imports finished products. According to the participants, the de-industrialisation of the South African economy such as the shrinking of the steel-making industry is a major impediment to expanding the PGMs product space which has led to a fragmented supply chain. The feeling amongst the participants is that the local PGMs manufacturing sector will have to import a lot more factors of production to fully take off and be successful.

The participants note that the local business sector and the government need to work together to correct the skills imbalance in the PGMs space and shift it towards the manufacturing of finished PGMs-related products in order the support the PGMs product space. Industrial policies such as science and innovation, immigration of highly skilled labour and fiscal policy are seen by participants as important drivers to spur and expand the export of locally

manufactured PGMs-related products. The participants feel that the government needs to repurpose the mineral and mining policy to support the expansion and diversification of the local PGMs product space. They highlight positive inroads in the PGMs product space such as successful R&D and the prototype of a haul truck powered by hydrogen fuel technology in Anglo Platinum-owned Mogalakwena opencast mine. Another R&D project of note is a collaborative effort between Sibanye-Stillwater, BASF & Impala to develop a tri-metal catalytic converter for light-duty fuel vehicles, a platinum-based autoclastic substitute from a palladium-based autocatalytic converter project. These projects will need government support in terms of a business-friendly environment, fiscal support in the form of rands and cents, and tax incentives to be fully monetised and competitive with global players and expand South Africa's product space.

4.6 Foreign Direct Investment

4.6.1 Findings pertaining to proposition 5: FDI will likely cause South African PGMs industry to diversify into manufacturing and export of finished PGMs products.

Twelve (10) in vivo codes were identified and grouped into three (3) code categories resulting in the four (4) themes presented in Table 4-11. The participants' perspectives on identified code categories are summarised in

Table 4-12.

The research questions to probe if foreign direct investment will create manufacturing new range of finished PGMs-related products and expand the existing product space in South Africa were:

- How do you feel about outward FDI impacts on knowledge creation and innovation in South Africa's PGMs industry?
- How do you feel about inward FDI impacts on knowledge creation and innovation in SA PGMs industry?

There is no full agreement on the benefits and the role of FDI in transforming the South African PGMs industry from export of raw and semi-finished PGMs products to exports of finished PGMs-related products. Participant 2 notes *'companies that invest here with us, in other words, what you call inward foreign direct investment, these guys, when they invest their nations benefit. You know, because they invest here, pull raw materials from us or whatever (semi-finished goods) and they send them to their countries, they benefit.'* 4:39 ¶ 105 in Participant

2_Final. Participant 1 echoes the same sentiments in the following quote, *'foreign direct investment, it does not necessarily mean it is for you. I know the theory says the foreign directed investment is coming there to actually make the country better but the primary objective is for that foreign direct investment to make more money'* 2:308 ¶ 550 – 551 in Participant 1_2022-12-22. However, the participants indicate positive spin-offs from OFDI and IFDI from local examples depicted in Table 4-10. Local examples of IFDI are BASF and Johnson Matthey and good examples of OFDI are Sibanye-Stillwater and Anglo-American mining companies.

Three code groups emerging from the in vivo codes are new knowledge, government interventions and new PGMs-related product manufacturing sectors. The participants agree that when done correctly, FDI brings new knowledge as mentioned by Participant 4, *'You do find opportunities where if there is such happening, some of [sic]South African based employees of that company might also get [sic]opportunity to be exposed in the foreign operations of that particular company, such that they get to learn more. You know, acquire more knowledge and specialist knowledge in terms of certain processes that they can bring back to the country'* 9:40 ¶ 182 in MBA Interview. The new knowledge will contribute to new process[sic] and new technology developing[sic] and [sic]absorbed by local human resources leading to expansion and add-ons on the existing PGMs product space as indicated in Table 4-12.

The participants note that OFDI learning opens new discussions which may lead to the development of new sectors. Participant 4 demonstrates the OFDI spin-off with the Sibanye-Stillwater OFDI experience in the quotes, *'as an example, Sibanye, one of you know, call it part of the deal going into the US was to get exposure into the recycling of PGM's[sic] which the US is doing very well and now we have that leg in the US operations."*'9:35 ¶ 172 in MBA Interview. Exposure to the US PGMs recycling industry has started a conversation in South Africa to go the same route, *'… I mean, our exposure to that process in the US has brought the conversation home and such that you know there's[sic] talks around it whether it has been advanced that[sic] I'm not sure. So, I'm just making an example to say, you know, diversifying geographically does expose the South African business into[sic] other opportunities within the same space that you operate.'* 9:36 ¶ 173 in MBA Interview.

Despite possible benefits of FDI such as developing human capabilities, bringing new technology and expanding the existing PGMs product space, the participants opine that FDI can lead to unfair exploitation of South Africa's resources and capabilities. According to the participants, unfair exploitation refers to selfish profit-making practices by multinationals and

the export of unfinished PGMs products and raw PGMs to host countries. The participants feel that government intervention, through a clear FDI policy, that is enforced and regulated within an investment-friendly legal framework is necessary to ensure a balance between the multinational propensity to make a profit and the country's strategic intent to expand and diversify the PGMs product space,

Table 4-12 indicates that the FDI legal framework to enforce compliance and measure FDI policy is of strategic importance to ensure rapid expansion and the diversification of the PGMs manufacturing sector.

Four themes emerge from the four code groups presented above namely: human resource capabilities, FDI policy, legislative framework and PGMs product space. Both OFDI and IFDI create new human resource capabilities and bring in new technology that should enable the manufacturing and export of finished PGMs products in South Africa. However, the participants note that a strong government FDI policy regulated by the legislative framework is key to ensuring the transformation of the South African PGMs industry in a balanced way, allowing multinationals to make a profit without unfair exploitation of local resources.

Therefore, the finding of Proposition 5 is that South Africa's FDI will likely cause the South African PGM mining sector to diversify into manufacturing and export of finished PGMs products when done in a balanced way, benefiting both the country and the multinationals.

Table 4-11. Clustering of Proposition 5 codes into code categories and themes

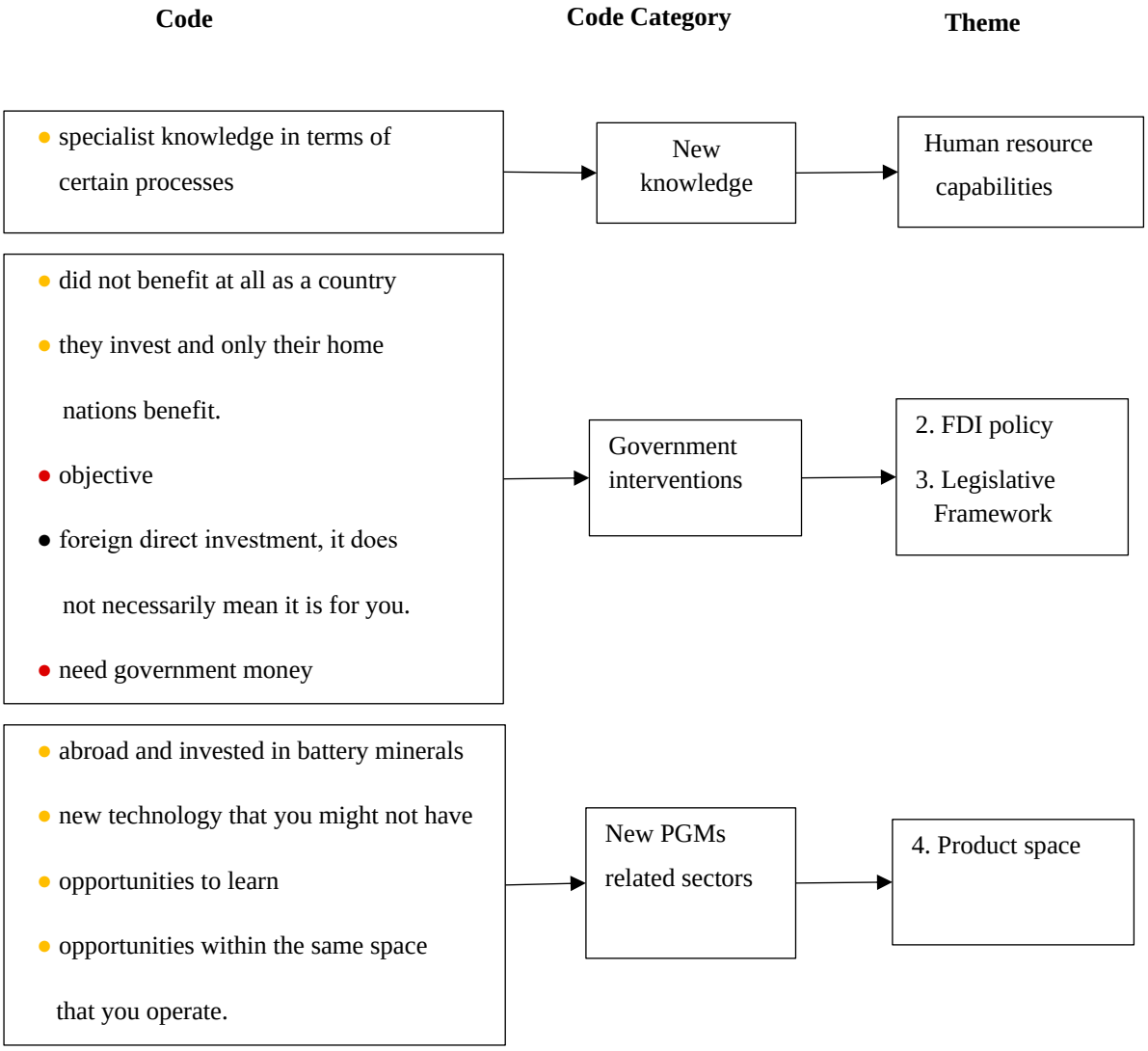

Table 4-12. Insights into emerging code categories from participants with respect to Proposition 5

Code Group	Quotation content
New knowledge	*'You do find opportunities where if there is such happening, some of South African based employees of that company might also get opportunity to be exposed in the foreign operations of that particular company, such that they get to learn more. You know, acquire more knowledge and specialist knowledge in terms of certain processes that they can bring back to the country'* 9:40 ¶ 182 in MBA Interview
Government interventions	*'Their (Chinese investors in deep South African Mines) objective is not only to make huge profit, it's actually to take the skill that they learn in South Africa, take it back and then. Creates those new gold mines that they are now running in their own country, but they were very intentional about that decision. So, you need if you want*

	to create similar systems in terms of platinum, you could have to be intentional. You need government money to actually do that, or force companies to go that route.' 2:312 ¶ 610 – 611 in Participant 1_2022-12-22 *'So, it's not just Sibanye-Stillwater that has diversified geographically. I mean, Goldfields and Anglo-American started a while ago and South Africa did not benefit at all as a country. Instead of those companies investing in better technologies to mine the deep mines in this country. You know, they walked away from the deep mines in this country, I mean, they weren't investing in West Africa in, in Chile, in Peru. Yeah, but I mean, what did you (South Africa) benefit? You (South Africa) did not benefit, a single ounce.'* 4:38 ¶ 100 in Participant 2_Final *'Companies that invest here with us, in other words, what you call inward foreign direct investment, these guys, when they invest their nations benefit. You know, because they invest here, pull raw materials from us or whatever (semi-finished goods) and they send them to their countries, they benefit.'* 4:39 ¶ 105 in Participant 2_Final *'Foreign direct investment, it does not necessarily mean it is for you. I know the theory says the foreign directed investment is coming there to actually make the country better but the primary objective is for that foreign direct investment to make more money'* 2:308 ¶ 550 – 551 in Participant 1_2022-12-22
	''The company we are working for is gone abroad and invested in battery minerals. I'm hoping that some of the South African people will end up working there and learn new skills that they could employ at home and convert more platinum into final products' 2:320 ¶ 542 in Participant 1_2022-12-22 *'It's always a good opportunity when foreign direct investment coming into South Africa whether that to support and grow existing businesses or more importantly, to set up new businesses or industries because the that comes with new technology that you might not have, a new process or an improved process of doing things and knowledge to expand on those bases.'* 9:38 ¶ 181 – 182 in MBA Interview
Product Space	*'As an example, for Sibanye, one of you know, call it part of the deal with going into the US was to get exposure into the recycling of PGM's which the US is doing very well and now we have that leg in the US operations.'* 9:35 ¶ 172 in MBA Interview *'Then South Africa, for a long time has been the leader in terms of PGM mining and exporting PGMs, we have, however not been in a position to develop recycling of PGM's in that sense. And then obviously brought that conversation home. I mean, our exposure to that process in the US has brought the conversation home and such that you know there's talks around it whether it has been advanced that I'm not sure. So, I'm just making an example to say, you know, diversifying geographically does expose the South African business into other opportunities within the same space that you operate.'* 9:36 ¶ 173 in MBA Interview

4.6.2 Summary of Proposition 5 findings: FDI will likely cause South African PGMs industry to diversify into manufacturing and export of finished PGMs products.

The participants share sentiments that there must be a balance between the multinational organisation's desire to make a profit and the government's objectives to transform the South African PGMs industry into a net exporter of finished PGMs-related products. The participants gave examples of South African mining companies abandoning deep mining activities and

diversifying globally to mine shallow deposits elsewhere. They too acknowledge positive feedback from Sibanye-Stillwater's experience in PGMs recycling learned in the US as an example of OFDI. Two successful R&D projects were also announced in the sector from partnerships between IFDI and locally based mining companies giving the country opportunities to acquire new technological know-how, develop new human capabilities, reskill existing human resources and expand local PGMs product space. The two IFDI R&D projects are, as discussed earlier, the hydrogen-powered haul truck at Mogalakwena and the tri-metal catalytic converter.

According to the participants, FDI allows South Africa the opportunity to develop human capabilities, acquire new processes to enhance current ones, acquire new technology and a chance to expand the existing range of locally manufactured PGMs-related products. The participants posit that a strong FDI policy under a business-friendly legal framework is required to realise a positive impact of FDI on the PGMs manufacturing sector. Four themes, namely: human resource capabilities, FDI policy, legal framework and product space emerged from the Proposition 5 research question.

4.7 Summary of findings

Five (5) drivers of vertical forward integration namely: international trade, institutional regime, innovation capabilities, the relatedness of capabilities and foreign direct investments were explored from the perspective of the selected participants. A resultant framework of the above drivers of vertical forward integration and associated themes is presented in Figure 4-2.

The findings show that institutional regime is the most important driver for forward vertical integration. Its responsibility is to lobby and adopt policies that will encourage the inflow of capital, technology, and skilled human resources into South Africa. The institutional regime is key to the endogenic development of own technology and human resource related to the manufacturing of finished PGMs-related products. The themes related to institutional regime include lobbying and raising of capital, fiscal policy, industrial policy, high skilled immigration policy, minerals and mining policy and science and innovation policy as shown in Figure 4-2. The findings show that the South African business sector can collaborate in R&D and produce complex PGMs-related products such as the hydrogen-fuelled haul truck and the tri-metal catalytic converter for light-duty fuel vehicles. The above finding shows that formal institutions

in South Africa has the capability to drive forward vertical integration in the PGMs mining sector.

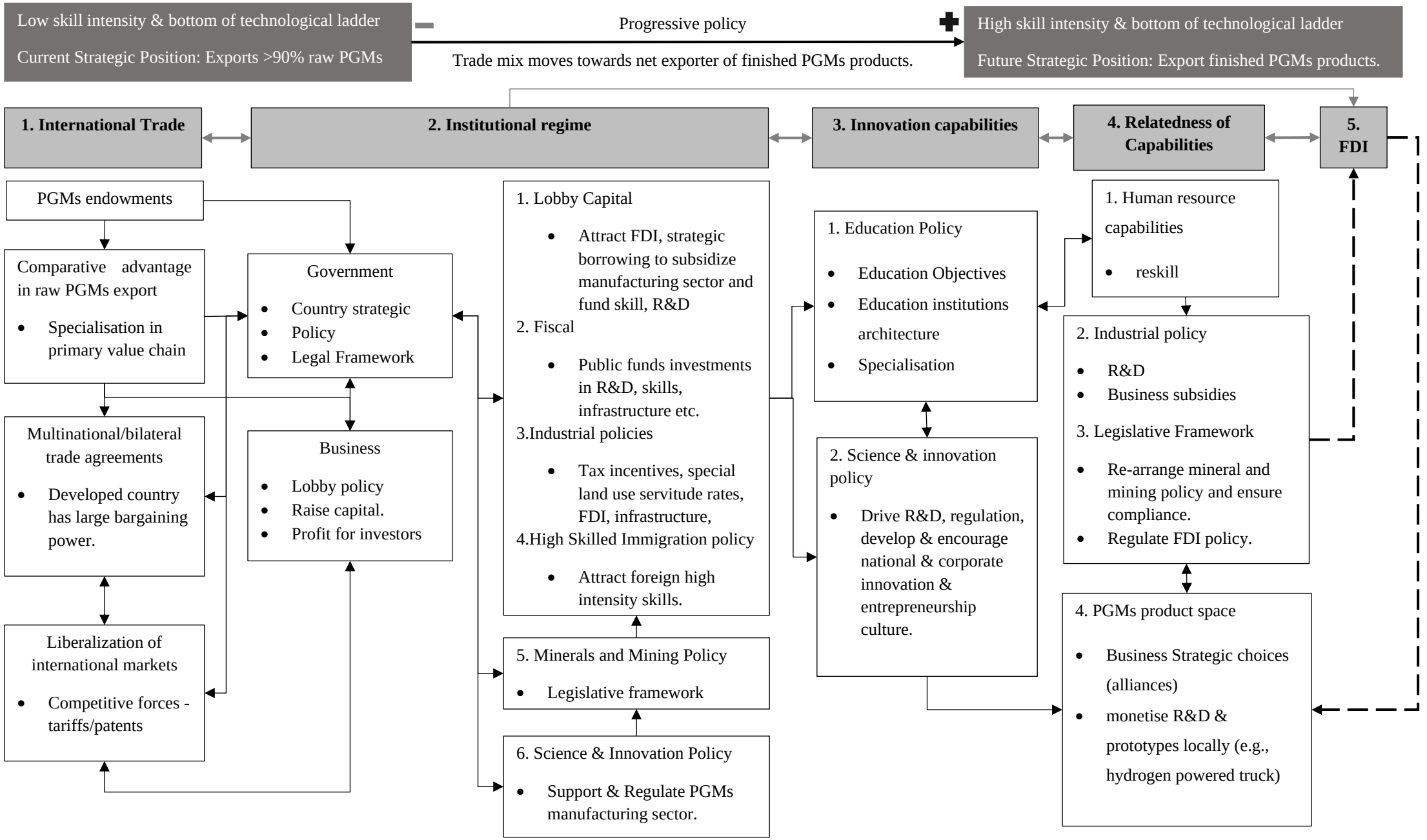

Figure 4-2. Summary of findings outlining framework of drivers of vertical forward integration and emerging themes in the context of the South African PGMs industry

The remaining four drivers, Figure 4-2: international trade, innovation capabilities, the relatedness of capabilities and foreign direct investments seem to be dependent on the institutional regime. The strength and effectiveness of these remaining four drivers are dependent on the policy adopted by the institutions and the strength of these institutions, in other words, the institutional capital.

The findings show that international trade drives vertical forward integration through multinational and bilateral trade agreements in PGMs and the liberalisation of international markets. The South African government must adopt a progressive trade policy and negotiate better deals with developed countries to support the local PGMs manufacturing sector. The trade deals should relax competitive forces such as the protection of technology and import tariffs on finished PGMs-related product exports imposed by developed countries. The themes: fair multinational and bilateral trade agreements and liberalisation of international markets will ease entry barriers and allow South Africa to manufacture finished PGMs-related products. The findings indicate that PGMs endowments are a barrier to vertical forward integration due to their short-term benefits to earn quick foreign capital during commodity booms, to mitigate the country's wicked problems. However, the government and business sector can escape the clutches of PGMs endowments by spending money on R&D, skills, and technology in downstream PGMs activities.

The findings show that South Africa's ability to manufacture finished PGMs products hinges on the capacity to develop the required skills and technology. This ability to develop new products is sustained by an innovation and entrepreneurship culture at both national and corporate levels. Innovation capabilities are enabled through the following themes: education policy, and science and innovation policy. The education policy theme has sub-themes: education objectives, education institutions architecture and specialisation in subject matter directed towards manufacturing of finished PGMs-related products. The findings suggest that education policy must be moulded by the state of the economy, what should drive the economy and the skills required to enable and match the new economy. South Africa has used scientific regulatory bodies such as SAMREC with great success. A scientific regulatory body, as guided by the science and innovation policy theme, will be responsible for setting standards and guidelines targeting R&D, the development of professional and skilled human resources, and driving innovation and entrepreneurship in the PGMs manufacturing sector. The Science and innovation policy will regulate the development of innovation capabilities.

South Africa is home to leading global companies in chemistry such as BASF and Johnson Matthey thus giving the country the necessary building steps to expand its existing PGMs-related product range. This existing manufacturing sector will densify the PGMs product space if supported by matching human resource capabilities, industrial policy, legislative framework, and technological advancements. The findings show that a small degree of the PGMs product space connectedness exists in South Africa, for example, successful R&D projects between local mining companies and multinationals as indicated above.

FDI is received with mixed feelings. On the negative side, the findings indicate that OFDI leads to capital, skills, and technology flight. The multinationals in South Africa tend to export raw platinum and semi-finished PGMs-related products to countries of origin. IFDI also tends to practise unsustainable economic exploitation of South Africa's natural resources without developing future industries. On the positive side, IFDI leads to the expansion of PGMs' product space through the import of technology, processes, new knowledge, and the immigration of highly skilled human resources. OFDI, on the positive side, results in technology, process and human skills spillover learned from foreign economies. An example of positive IFDI in PGMs product space, as discussed earlier, is the development of the tri-metal catalytic converter. The green mining culture adopted by Sibanye Stillwater is a good example of ESG spillovers from its recent geographical diversification through OFDI.

Chapter 5: Discussions of the findings

This chapter discusses the linkages between the literature review (Figure 2-1) in Chapter 2 and research findings (Figure 4-2) in Chapter 4. The chapter concludes with an input-output model derived from the literature review and the research findings. This model illustrates the linkages of drivers of vertical forward integration and how they will work together to migrate the economy from a net exporter of resource-intensive products to technologically sophisticated finished products in the context of South Africa's PGMs industry.

The discussions of findings pertaining to the drivers of vertical forward integration are presented from section 5.1 to section 5.5.

5.1 International Trade Theory

5.1.1 Discussions of findings pertaining to Proposition 1a: Large PGMs resources and reserves in South Africa are likely to loc South Africa in export of primary refined PGMs products.

The findings of Proposition 1a indicate that South Africa's PGMs trade pattern is dominated by the export of primary and semi-finished PGMs products due to its large PGMs resources and a high degree of specialisation in the primary PGMs value chain. The findings also indicate that South Africa will likely remain in that position unless the government adopts progressive policies to purposefully change the export mix towards the export of finished PGMs-related products. Leamer (1984, 1995) and Nazarczuk et al. (2018) assert that natural resource endowments and a high degree of specialisation in primary value chains result in comparative advantage in the export of resource-intensive goods support the above findings.

Progressive multinational and bilateral trade agreements and the liberalisation of international markets themes emerging from international trade, add another perspective to trade patterns in PGMs. In agreement with Eaton and Kortum (1999), the findings show that developed countries use intellectual property patents to protect their new technologies. These patents help developed countries to maintain their comparative advantage in the export of finished PGMs-related products. The intellectual property patents and tariffs on finished PGMs products from developing countries act as barriers to entry. These competitive forces prevent developing countries from climbing the technological ladder and participating in the manufacturing and export of finished PGMs-related products.

Therefore, South Africa's government's strength to negotiate fair trade deals and the liberalisation of international PGMs'-related products manufacturing sectors will enable South Africa to change its trade mix.

5.1.2 Discussions of findings pertaining to Proposition 1b: Technological know-how will transform South Africa into a net exporter of finished PGMs-related products.

Deardorff (2007), Eaton and Kortum (1999) and Petralia et al. (2017) posit that technological difference is key for developing countries to diversify their export mix from exports of primary resource-intensive products to finished value add products. The findings of Proposition 1b did not reach a similar conclusion because the participants see institutional capital in terms of policy maturity and willingness as a determinant to change the export mix to finished value-added products. In other words, institutional capital comes first because it is required to develop the required technology.

Proposition 1b findings show that South Africa does not have the technological know-how to manufacture PGMs-related products at an industrial scale. However, the findings show that skills can be imported through the high skilled immigration policy and technology can be copied or brought into the country through the FDI policy. These means of technological know-how diffusion into South Africa align with Eaton and Kortum (1999), and Maskell and Malmberg's (1999) findings.

The findings of Proposition 1b require South Africa's institutional capital to develop to the stage where it can adopt progressive policies allowing human capital to absorb new foreign technologies supporting the manufacturing of finished PGMs-related products (Asongu & Tchamyou, 2018; Razmi & Blecker, 2008). In summary, South Africa is not manufacturing PGMs-related products because the policy has not yet been formulated as indicated on Table 4-4.

5.2 Institutional regime

5.2.1 Discussions of findings pertaining to Proposition 2: Progressive policies implemented by the formal institutions will cause gradual diversification of South Africa's PGMs industry into a net exporter of finished PGMs-related products.

The themes emerging from the drivers are institutional regimes, which position the formal and informal institutions as enablers of competitive forces required to diversify the PGMs' mining

sector into a manufacturing sector. In agreement with Asongu and Tchamyou (2018), Razmi and Blecker (2008), the findings of Proposition 2 suggest that the government must adopt policies that will encourage: government accountability and the ability to raise capital, liberalisation of markets and FDI, R&D, fiscal spending on PGMs' manufacturing sector, immigration of skilled and professional human capital as indicated in Figure 4-2. The Proposition 2 themes: lobby capital, fiscal policy, industrial policy, high skilled immigration policy, minerals and mining policy, science and innovation policy are industrial and market-orientated policies.

There is very little coordination and alignment between the government and the business sector to expand the existing PGMs' manufacturing sector in South Africa as indicated by skills imbalance and de-industrialisation. However, the South African business sector enterprises can collaborate on agreed interventions amongst themselves as illustrated by collaborations between Impala, Sibanye-Stillwater, and BASF. According to Cortinovis et al. (2017), the strength of the business sector can drive the diversification of the PGMs mining sector to the finished PGMs products manufacturing sector in the absence of strong formal institutions. The business sector together with the wider society can diversify the PGMs industry if the South African government is unable to implement policies fit to change the country's export mix.

5.3 Innovative capabilities

5.3.1 Discussions of findings pertaining to Proposition 3: Education and innovation strategies in South Africa will likely create diversification of South African PGMs industry.

Proposition 3's findings show that education will give South Africa the capability to create new knowledge, absorb foreign knowledge, create new technology and develop the capability to manufacture finished PGMs-related products. Like Asongu and Tchamyou's (2018) observations on South Korean education and innovation strategies, Proposition 3's findings show that education and innovation policies must be shaped by the state of the current economy, the current factors of production in abundance, the future economy and the skills required to match the future economy. In the case of South Africa, the country is blessed with PGMs and is a net exporter of primary and semi-finished PGMs. The future economy is to export finished PGMs-related products that will require professional and skilled human resources and technological know-how.

Using South Korea's education policy, Asongu and Tchamyou (2018) postulate that education should be adaptive to evolve with the economic and political institutional environments. Therefore, the is a need for a scientific regulatory body to ensure that the education policy is adaptive and can improve the strategic human resource to release the latent comparative advantage in the manufacturing of finished PGMs-related products.

The Proposition 3 findings are inclined more towards endogenic innovation-based strategies to develop innovation capabilities. The findings propose the early introduction of innovation curriculum at the school level, specialisation in mathematics and sciences, and the introduction of educational institutions such as institutes of technology. These innovation strategies should focus on the PGMs' product space, for example, associated supply and value chain activities to support the aspired strategic position to be a net exporter of finished PGMs-related products. Gao (2018) notes that the endogenic innovation-based differentiation strategy worked for the Chinese telecom equipment company. South Africa has unrealised the potential to unlock latent comparative advantage in the export of finished PGMs-related products if it is successful in rearranging its human resources through education and endogenic innovation strategies mentioned above.

The science and innovation policy is targeted at encouraging finished PGMs-related products R&D, development, and regulation of new skills, promoting linkages in the PGMs' product space, instilling, and promoting an innovation and entrepreneurship culture at national and corporate levels. A well-crafted and functional education policy and, science and innovation policy should enable South Africa to create tacit knowledge crucial for the consolidation of new technologies and for giving the country's human resources the technological know-how capacity to create new products and services (Asongu & Tchamyou, 2018).

5.4 Relatedness of capabilities

5.4.1 Discussions of findings pertaining to Proposition 4: South Africa's PGMs product space network density is likely to sustain diversification and expansion of current PGMs-related products.

South Africa exports over 90% of its PGMs and consumes less than 7% of its annual production locally. South Africa's PGMs mining industry also displays a high degree of specialisation in PGMs and base metal smelting and refinery processes. South Africa is also home to Johnson Matthey and BASF, which represent a segment of multinationals manufacturing semi-finished

PGMs-related products with a wide range of specialities in metal alloys, jewellery, green energy, and chemistry. Based on the above findings, South Africa's PGMs industry can be described as an exporter of resource intensive PGMs products and related PGMs semi-finished products. According to Hidalgo et al. (2007), an industry that produces resource-intensive products and semi-finished products has a less connected product space.

The findings of Proposition 3 are that the PGMs product space in South Africa is fragmented because of the following reasons: deindustrialisation that weakened the supply chain, propensity by multinationals such as Johnson Matthey to export semi-finished goods and specialisation in primary mining processes. These conditions result in a less connected product space as noted by Hildago et al. (2007). In line with Hausmann and Klinger's (2007) observations, it will be difficult for South Africa to produce finished PGMs-related products due to its less connected PGMs product space.

Boschma (2017) and Coniglio et al. (2018) in their affirmation of Hidalgo et al. (2007) and Hausmann and Klinger (2007) note that existing capabilities like human capital, technology, and institution regime can be arranged in different ways to produce new products and expand the product space. Similarly, the findings of Proposition 3 propose the rearrangement of human capital through reskilling of mining professionals and skilled artisans into the manufacturing of finished PGMs products. The findings also suggest a re-arrangement of industrial policies and legislative framework to enhance formal institutional capital by clarifying intent to manufacture finished PGMs products and enforcing participation. The business institutions can be re-arranged through business strategic choices like forming alliances to share technology and R&D to produce PGMs-related products.

Proposition 4 findings indicate that the automotive assembly sector, platinum alloys sector, chemistry and green energy sectors, and the jewellery manufacturing sectors are likely to succeed in the diversification of South Africa's PGMs. These sectors are likely to succeed in diversifying the PGMs industry because they have existing R&D support from both government and business, existing skills and technology and wide range of government interventions such as tax incentives. Coniglio et al. (2018) note that product space networks supported by existing capabilities, such as the ones above, are likely to succeed in diversifying the economy. Therefore, such networks must be targeted by progressive industrial policies to release the latent comparative advantage in the finished PGMs-related products manufacturing sector.

5.5 Foreign Direct Investment

5.5.1 Discussion of findings pertaining to proposition 5: FDI will likely cause South African PGMs mining sector to diversify into manufacturing and export of finished PGMs products.

The finding of Proposition 5 is that FDI will contribute positively to diversifying the PGMs mining sector into the PGMs manufacturing sector. The FDI positive contributions will be realised if there is a balance between the multinational organisations desire to make a profit and the government's objectives to transform the South African PGMs industry into a net exporter of finished PGMs-related products. FDI can result in capital, intellectual property and skills flight, deindustrialisation, and the collapse of local manufacturing enterprises due to competitive forces. The findings of Proposition 5 also indicate that multinationals pull raw materials and semi-finished products to countries of origin thus reducing the host country's capability to manufacture sophisticated finished PGMs-related products. Lim and Teo (2019) note that OFDI results in the flight of capabilities necessary to diversify the economy such as skills, capital, and technology while Jin et al. (2019) assert that IFDI increases competitive forces which can be harmful to local enterprises. Multinationals tend to have superior technology and processes that give them a competitive advantage against local enterprises. Thus, FDI can have a negative impact and deindustrialise the country when it is not well regulated.

In agreement with the Andrijauskiene and Dumčiuvienė (2019) study of 28 EU member states, Proposition 5 findings show that IFDI and OFDI bring new technology, knowledge, and processes and can add new sectors to the existing industry. OFDI contributes positively to the country of origin's product space by purchasing foreign technology and gaining access to high-intensity factor inputs. South Africa has not fully benefited from OFDI, however, there is positive talk about local recycling of PGMs which is an overspill from OFDI activities in the United States of America.

There are many examples of positive IFDI in South Africa as demonstrated by the BASF example. IFDI also brings new knowledge and technology and contributes positively to R&D and the development of human resource skills. The findings of Proposition 5, Figure 4-2, show that FDI has a direct effect on the relatedness of capabilities and innovation capabilities. FDI brings new sectors in the existing industry that come along with new technology, processes and skills increasing the product range and connectedness of the products resulting in a denser

product space network. New knowledge and R&D brought by FDI also contribute positively to the country's ability to create new products through an exogenic process.

5.6 Summary of Discussions

A summary of discussions from the literature review and research findings is presented below in Figure 5-1 in the form of an input and output model. The model depicts how immobile PGMs reserves will be transformed into to finished PGMs-related products releasing the latent comparative advantage in exports of finished PGMs-related products, Figure 5-1. The model calls for the institutional regime driver as a transforming input. The remaining four drivers namely FDI, international trade, innovative capabilities and relatedness of capabilities are important components in the transforming process. The transforming process entails the creation of new knowledge and new technology, absorption of foreign knowledge and technology, liberalisation of international trade and entrepreneurship. Entrepreneurship is required to expand the PGMs product range and should happen at national and corporate levels and be driven by national and corporate innovation and entrepreneurship cultures. Liberalisation of international trade in PGMs refers to the loosening of competitive forces such as tariffs and sharing of intellectual properties to allow developing countries, such as South Africa, to climb the technological ladder and manufacture finished PGMs-related products. This model, Figure 5-1, requires a strong institutional regime to enable competitive forces by adopting policies that encourage the liberalisation of markets, foreign direct investment (FDI), endogenic creation of knowledge and technology, absorption of foreign technologies and knowledge, expansion and modernisation of infrastructure, as supported by Asongu and Tchamyou (2018), and Razmi and Blecker (2008).

Figure 5-1 depicts those innovative capabilities that can be acquired through two strategies namely the endogenic and exogenic differentiation strategies. As noted by Gao (2018), an endogenic innovation-based differentiation strategy will enable countries and their local enterprises to develop core technologies and disrupt innovative low-cost offerings and superior customer service. These competitive forces will enable South Africa to introduce new and develop existing products at a lower opportunity cost. The innovative capabilities can also be acquired and supported through FDI policy supported by an investment friendly FDI legal framework to ensure a balance between multinationals' profit-making objectives and government objectives to create an inclusive economy.

Innovation capabilities acquired through endogenic and exogenic innovation-based strategies will increase the PGMs' product network density, Figure 5-1. South Africa's PGMs industry has acquired specialisation in PGMs refinery, autocatalytic converters, chemistry, and jewellery and has enjoyed some degree of support from the government through minerals and mining policy and FDI policy. These existing capabilities present South Africa with opportunities to densify its PGMs product network with target policies supported by the legal framework.

The themes associated with the five drivers of vertical forward integration depicted in Figure 4-2 are summarised below in Table 5-1. The research questions findings and researchers such as Asongu and Tchamyou (2018), Razmi and Blecker (2008), and Cortinovis et al. (2017) indicate that these themes indicate in Figure 4-2 require a strong policy and legal framework maturity to ensure successful migration of South Africa's PGMs economy to a net exporter of finished PGMs-related products.

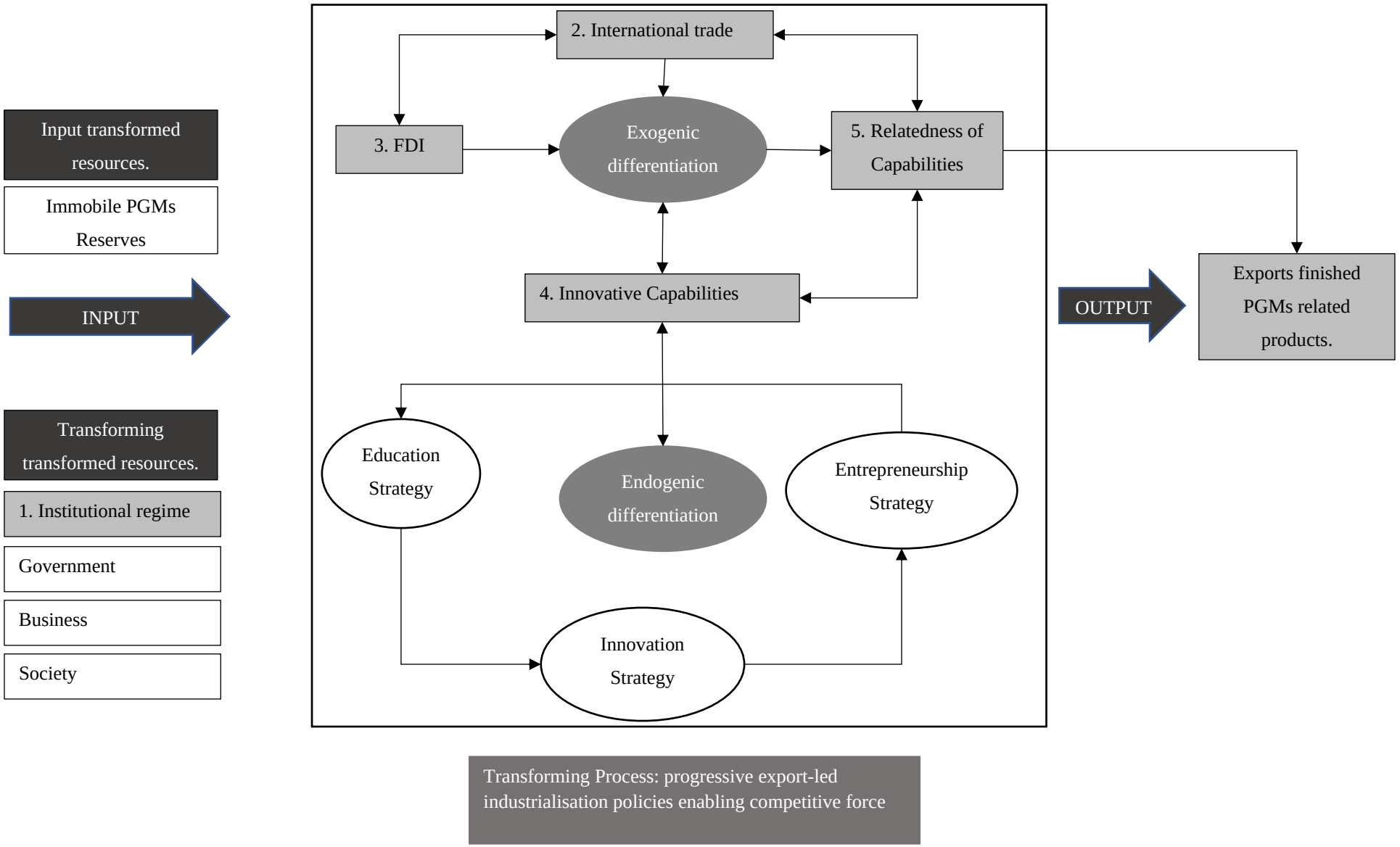

Figure 5-1. Input-output model illustrating dynamics of drivers of vertical forward integration in South Africa's PGMs industry.

Table 5-1. Summary of themes associated with drivers of vertical forward integration.

	Institutional Regime	Innovation capabilities	International Trade	Relatedness of capabilities	FDI
Themes	**1. Lobby Capital** • Attract FDI, strategic borrowing to subsidise manufacturing sector and fund skill, R&D **2. Fiscal** • Public funds investments in R&D, skills, infrastructure etc. **3. Industrial policies** • Tax incentives, special land use servitude rates, FDI, infrastructure, **4. High Skilled Immigration policy** • Attract foreign high-intensity skills. **5. Minerals and Mining Policy** • Legislative framework **6. Science & Innovation Policy** • Support & Regulate PGMs manufacturing sector.	**1. Education Policy** • Education Objectives • Education institutions architecture • Specialisation **2. Science & innovation policy** • Drive R&D, regulation, develop & encourage national & corporate innovation & entrepreneurship culture.	**1. Comparative advantage in raw PGMs export** • Specialisation in primary value chain **2. Multinational/bilateral trade agreements** • Developed country has large bargaining power (remove trade barriers) **3. Liberalization of international markets** • Competitive forces - tariffs/patents	**1. Human resource capabilities** • Reskill e.g., metallurgy, engineering disciplines. **2. Industrial policy** • R&D • Business subsidies **3. Legislative Framework** • Re-arrange mineral and mining policy and ensure compliance. • Regulate FDI policy. **4. PGMs product space** • Business Strategic choices (alliances to share R&D) • monetise R&D & prototypes locally (e.g., hydrogen-powered truck	**1. Human resource capabilities** • New knowledge **2. FDI policy** **3. Legislative Framework** **4. PGMs product space** • Business Strategic choices (alliances) • monetise R&D & prototypes locally (e.g., hydrogen-powered truck

Chapter 6: Conclusions

The PGMs production and export data for the period 2009 to 2019 shows that South Africa's PGMs industry specialises in exports of refined and semi-finished PGMs-related products, Figure 1-1 and Figure 1-2. From 2009 to 2019, Figure 1-2, South Africa exported 90% of its total production in refined PGMs and semi-finished products, and 7% of the total production was consumed locally (Minerals Council of South Africa [MCSA], 2019). The top ten export mix data for the period January 2015 to June 2021 shows that 85% of export value in ZAR consists of primary natural minerals, refined minerals, and semi-finished goods, Table 1-1.

According to Bassino and Williamson's (2015) study of the Southeast Asian economies before World War 2, comparative advantage in the export of resource-intensive products impaired these economies' ability to export finished value add products. The PGMs production and export data supported by the top ten export goods value in ZAR depicted in Figure 1-2 and Table 1-1, show that South Africa's PGMs industry is suffering the same problem as the Southeast Asian economies before World War 2 as observed by Bassino and Williamson (2015).

The main research problem is to define the drivers of vertical forward integration to migrate the South African PGMs industry from a net exporter of refined and semi-finished PGMs-related products to an exporter of finished PGMs-related products. Therefore, the objective of the research is to explore the themes around drivers of vertical forward integration in the context of the South African Platinum industry. Furthermore, the research objective is to develop a working framework illustrating linkages between the drivers of vertical forward integration and how these drivers will work to transform South Africa's PGMs industry export pattern.

To meet the objectives of the study and contribute to resolving the research problem, five drivers of vertical forward integration were identified from the literature as presented in Figure 2-1. The qualitative research methodology was used for this research to establish an in-depth understanding of the drivers required to change the South African PGMs industry trade pattern into a net exporter of finished PGMs-related products. Structured research questions were designed to get insights about each proposition linked to a specific driver of forward vertical integration.

The propositions and research questions are shown in the research instrument, Appendix B. Research instrument. The five drivers of vertical forward integration and related propositions and insight-seeking questions are listed in section 3.3.

Multiple view of diversification drivers by participants led to various interesting themes that gave good insights into how to diversify South Africa's PGM industry.

6.1 International trade

6.1.1 Proposition 1a: Large PGMs resources and reserves in South Africa are likely to lock South Africa in export of primary refined PGMs products.

South Africa has a comparative advantage in the export of refined and semi-finished PGMs-related products. This comparative advantage is from large PGMs endowments, years of specialisation in the primary PGMs value chain, large R&D in the primary value chain in both technology and skills development, and a deliberate country strategic position to be known as a mining country.

Bilateral and multilateral trade agreements do not encourage developing countries to manufacture finished PGMs-related products due to entry barriers such as tariffs and intellectual property patents. Therefore, South Africa will likely remain an exporter of raw and semi-finished PGMs products due to its relative comparative advantage in exports of PGMs resource-intensive products, international trade agreements and non-liberal international markets.

However, the liberalisation of international trade by loosening intellectual property patents will encourage the diffusion of new technology and new knowledge to developing countries like South Africa. This will result in progressive technological development and the manufacturing of sophisticated goods. The removal of tariffs will also encourage the diffusion of cheaper finished PGMs-related products in developed markets, resulting in denser PGMs product networks in developing countries.

6.1.2 Proposition 1b: Technological know-how will transform South Africa into a net exporter of finished PGMs-related products.

Historically, South Africa has not invested in downstream activities in the PGMs value chain. As a result, it will not be fair to assess Proposition 1b. However, the research finding is that South Africa is not participating in PGMs downstream activities because its policy on

manufacturing finished PGMs-related products is not mature and in full implementation. The finding indicates that technological know-how can be copied or imported through FDI. Therefore, the lack of technological know-how is not the reason that South Africa is not manufacturing sophisticated PGMs-related products. The reason that South Africa is not manufacturing finished PGMs-related products on a large scale is that the policy is not there yet.

The conclusion of Proposition 1b is that policy maturity and willingness by the government and business sector will enable technological know-how to migrate the South African PGMs industry from a net exporter of primary refined and semi-finished PGMs products to finished PGMs-related products.

6.2 Institutional regime

6.2.1 Proposition 2: Progressive policies implemented by the formal institutions will cause gradual diversification of South Africa's PGMs industry into a net exporter of finished PGMs-related products.

The role of the government is to position South Africa as a finished PGMs-related products exporter by implementing policies, systems, and structures to support vertical forward integration in the PGMs industry. Business' role is to lobby the government to implement investment-friendly policies and to exploit opportunities created by those policies for sustainable economic gains.

The successful R&D and working machinery prototypes such as the hydrogen-powered truck and the tri-metal catalytic converter for light-duty fuel vehicles show that business institutions in South Africa can diversify the PGMs industry in the absence of a strong government policy.

The following themes emerging from the institutional regime driver insights are necessary for South Africa to develop a comparative advantage in the export of finished PGMs products.

- Fiscal policy - spending on R&D and skills development
- Industrial policy – special servitudes for PGMs manufacturing sector land use, tax credits for R&D, tax credits for future skills development, functional infrastructure
- High Skilled Immigration policy – attract foreign talent for PGMs manufacturing sector.
- Science and innovation policy – PGMs manufacturing regulatory body.

- Minerals and mining policy – a legislative framework to tie mining licenses to downstream activities such as manufacturing and R&D

The conclusion on Proposition 2 is that South Africa will develop a comparative advantage in the export of finished PGMs-related products if it is enabled by national industrial policies such as reducing total production costs by cutting taxes, introducing subsidies to reduce the impact of tariffs imposed by developed countries, special rates for PGMs manufacturing sector land use, increasing public funds spending on R&D, attracting foreign talent, cheap electricity and world-class infrastructure.

6.3 Innovative capabilities

6.3.1 Proposition 3: Education and innovation strategies in South Africa will likely create diversification of South African PGMs industry.

South Africa does not have active education and innovation strategies because the educational institutions are not supporting innovation. Historically, innovation has only been introduced in institutions of higher learning with no to little mention in lower education. Therefore, the education institution architecture must be rearranged to render curricula to support the development of innovative capabilities. The changes must include increasing the number of institutes of technology and the early introduction of innovation and entrepreneurship curricula in basic education.

The research answers to Proposition 3 suggest more endogenic education and innovation strategies by identifying the factors of production the country has in abundance, the current trade mix, what drives today's economy, what the future economy is and what skills and technologies are needed to enable the future economy. That way South Africa will be able to develop targeted education and innovation strategies to develop innovation capabilities to transform the PGMs export mix.

Two (2) themes emerged from Proposition 3 research questions, namely: education policy, and science and innovation policy. The insights with respect to education policy are summarised below.

1. Education Objectives – must develop professional and skilled human capital to support the finished PGMs products manufacturing.

2. Educational institution architecture – build and resource institutions of technology to develop human resources and technology to support a competitive PGMs manufacturing sector.
3. Specialisation in education – introduce subject matter experts in mathematics and science, innovation, and entrepreneurship earlier in learners' development. The participants see this as a key to developing national innovation and entrepreneurship culture.

The science & innovation policy drives forward vertical integration by enabling innovation capabilities monitoring and lobbying for R&D and skills development in PGMs' downstream activities. The science and regulation policy must also regulate the quality of education to ensure adaptive human resource capital.

A national and corporate innovation and entrepreneurship culture has proved to be a differentiator between countries with comparative advantage in the export of sophisticated goods and those with comparative advantage in the export of resource-intensive goods. Therefore, the science and innovation policy must address the cultural issues to entrench effective education and innovation strategies to support the forward vertical integration of the South African PGMs industry.

The conclusion to Proposition 3 is that education and innovation strategies in South Africa do not exist or are still in the infancy stage, however, rapid introduction and early implementation will result in the forward vertical integration of the PGMs mining sector into the finished PGMs-related products manufacturing sector.

6.4 Relatedness of capabilities

6.4.1 Proposition 4: South Africa's PGMs product space network density is likely to sustain diversification and expansion of current PGMs-related products.

South Africa's PGMs industry exports over 90% of its annual production in the form of refined and semi-finished PGMs products. The PGMs industry exhibits a high degree of specialisation in the primary PGMs value chain or upstream supply chain activities. The above intrinsic characteristics of the South African PGMs industry coupled with the large PGMs endowments resulted in a less dense PGMs product network. The findings of Proposition 4, in agreement with literature review conclude that it will be difficult to densify the PGMs product space in South Africa. However, South Africa has existing industries in the form of multinationals such

as BASF and Johnson Matthey, existing science and innovation policy, minerals and mining policy, existing professional and skilled human resources and FDI policy to expand the manufacturing of finished PGMs-related products. These existing capabilities can be re-arranged to expand the product space for example:

- re-arrangement of human capital through reskilling of mining professionals and skilled artisans into manufacturing finished PGMs products.
- re-arrangement of industrial policies and legislative frameworks to enhance formal and informal institutional capital by clarifying intent to manufacture finished PGMs products and enforcing participation through a business-friendly legal framework.
- business can be re-arranged through business strategic choices like forming alliances to share technology and R&D to produce PGMs-related products.

In conclusion, although South Africa has a small PGMs manufacturing footprint, it has highly specialised capabilities and small degree of relatedness in the PGMs sector that could enable the manufacturing of finished PGMs-related products.

6.5 Foreign Direct Investment

6.5.1 Proposition 5: FDI will likely cause South African PGMs mining sector to diversify into manufacturing and export of finished PGMs products.

South Africa has a working FDI policy and several multinationals doing business in the country. The multinationals currently active in South Africa display both the negative and the positive characteristics of FDI. Multinationals export refined and semi-finished PGMs-related products outside of South Africa. Locally perfected mining technologies are monetised elsewhere outside South Africa. The above activities, carried by multinationals result in skills flight, intellectual property flight, dedensification of the PGMs product network and deindustrialisation of the South African economy. These negative characteristics of FDI are normally associated with IFDI. OFDI has mainly resulted in capital flight resulting in the sterilisation of deep PGMs and gold resources due to a lack of innovative technologies. South African mining houses are not investing in ultra-deep level mining technology but are rather diversifying geographically and mining shallower resources.

The positive side of IFDI is that it is a means of diffusing new technology, new knowledge, new products, and foreign capital in the PGMs industry. Two good examples of FDI projects were mentioned earlier. OFDI allows the home countries to purchase foreign technologies and

gain access to high-intensity factor inputs in host countries. These capabilities are expected to benefit home countries with the overspill effect.

The conclusion to Proposition 5 is that FDI will likely cause the South African PGMs mining sector to diversify into manufacturing and the export of finished PGMs products only when it is regulated by investment-friendly regulatory frameworks mitigating the negative impacts of IFDI and OFDI.

6.6 Recommendations

According to Coniglio et al. (2018), the existing capabilities will determine the success and the degree to which forward vertical integration will occur in the economy. The research findings show that South Africa has highly specialised professional and skilled human resources in the PGMs mining sector including PGMs smelting and refinery. South Africa also has existing policies supporting beneficiation in the PGMs sector and a good FDI policy. The country hosts some world-class multinationals who are actively participating in the PGMs manufacturing sector. These findings present the opportunity for forward vertical integration in the PGMs industry with minimal risk of failure. Based on the above research findings and conclusions the following recommendations are presented:

1. Incentivise mining companies to do forward vertical integration through partnerships with manufacturing enterprises. This change in business model will encourage mining houses to reskill their professionals in engineering fields to switch to manufacturing technologically sophisticated PGMs-related products to maximise the profits resulting in a denser product space.
2. The government should buy a stake in an automotive assembler of choice and commit public funds to start local manufacturing of electronic components, this will provide the required capital outlay and reduce the risk of failure.
3. Implement FDI legal framework regulating local manufacturing of equipment perfected or developed using local innovative capabilities such as hydrogen-powered technology perfected at Anglo-American Mogalakwena Mine and the tri-metal catalytic converter for light-duty fuel vehicles. This recommendation will prevent intellectual property flight and increase the PGMs' product space density.

The above recommendations will densify the PGMs product space creating even more opportunities to add new PGMs-related products to the industry by doing forward vertical integration.

6.7 Suggestions for future research

This research gave good insights into themes associated with drivers of forward vertical integration. However, the following suggestions are made for future research to add to the findings of this study:

1. The sampling method was purposive by design and excluded candidates from metallurgy and the marketing divisions in the mining sector. The main reason was to narrow the study only to the PGMs mining sector's major players. Future studies must use a probabilistic sampling method to cover a wide range of divisions in the industry to have a representative understanding of drivers of vertical forward integration in the PGMs industry from all key players.
2. A quantitative study of drivers of vertical forward integration to test their relationships and impacts on PGMs product diversification.

6.8 Limitations of the study

The study has the following limitations:

1. The sampling method used in this study was non-probabilistic by choice due to research delimitation. As a result, the sample excludes other important players in the industry such as marketing, who could give different insights into drivers like relatedness of capabilities.
2. The study reached saturation point quickly (three participants), probably due to the homogeneous sample. Future samples must have a broader demographic and wider skill range.
3. The study was too broad, sacrificing finer details. Therefore, future research must concentrate on one driver to explore related themes in detail.

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Appendix A. Participation Information Sheet

Dear Sir/Madam <Potential Participant>

My name is Simon Pheto, and I am a Masters student in Business Administration at the University of the Witwatersrand, Johannesburg. As part of my studies, I must undertake a research project, and I am investigating diversification of exports in the Platinum Group Metals (PGMs) industry in South Africa under the supervision of Dr Oro. The aim of this research project is to find out the drivers of diversification necessary to change the PGMs export mix.

As part of this project, I would like to invite you to take part in an interview. This interview will involve in-depth reflection on drivers of diversification of export of primary natural PGM to PGM manufactures in a standardise open-ended interview. The interview will take approximately one hour. With your permission, I would like to record the interview using a digital device.

There will be no personal costs to you if you participate in this project. You will not receive any direct benefits from participation but there are no disadvantages or penalties if you do not choose to participate or if you withdraw from the study. You may withdraw at any time or not answer any question if you do not want to. The interview will be completely confidential and anonymous as I will not be asking for your name or any identifying information, and the information you give will be held securely and not disclosed to anyone else. I will be using a pseudo name to represent your participation in the report. If you experience any distress or discomfort at any point in the process, we will stop the interview or resume another time.

If you have any questions during or afterwards about this research, feel free to contact me on the details written below. This study will be written up as a research report which will be available online through the university library website. If you wish to receive a summary of this report, I will be happy to send it to you. The data collected from this research project will be stored in a password-protected computer for two years. With your permission, the data collected from this research project may be used by other researchers. If you have any concerns or complaints regarding the ethical procedures of this study you are welcome to contact the University Human Research Ethics Committee (Non – Medical), telephone +27(0) 11 717 1408, email hrec-medical.researchoffice@wits.ac.za.

Yours sincerely

Simon Pheto
2404993@students.wits.ac.za – 083 395 7635

Signed:

Date:

Appendix A. Informed consent

Title of project: Exploring drivers of vertical forward integration in South African Platinum Mining Industry

Name of researcher: Simon Pheto

I, ……, agree to participate in this research project. The research has been explained to me and I understand what my participation will involve. I agree to the following:

(Please tick the relevant option below)

	Yes	**No**
I agree that my participation will remain anonymous	Y	N
I agree that the researcher may use anonymous quotes in his research report	Y	N
I agree that the interview may be audio recorded	Y	N
I agree that the information I provide may be used anonymously after this project has ended, for academic purposes by other researchers, subject to their own ethics clearance being obtained	Y	N

Signature of participant ……...

Date: ……

Appendix B. Research instrument

No	Proposition	Interview Question	Follow-up questions
1	Proposition 1a: Large PGMs resources and reserves in South Africa are likely to lock South Africa in the export of primary refined PGMs products.	What do you think about the sustainability of SA's strategic position as the number one exporter of PGMs? Is the position good for the country?	Why is the country number one PGMS exporter?
	Proposition 1b: Technological know-how will transform South Africa into a net exporter of finished PGMs-related products.	How would you describe South Africa's local capability to develop its own technologies and absorb foreign technology? What is lacking to develop these capabilities?	Can local technological know-how expand PGMS's manufactures?
2	Proposition 2: Progressive policies implemented by the formal institutions will cause the gradual diversification of South Africa's PGMs industry into a net exporter of finished PGMs-related products.	What is the role of government institutions in diversifying the PGMs industry? How do you feel about the role of business institutions in the South African PGMs sector?	
3	Proposition 3: Education and innovation strategies in South Africa will likely create the diversification of the South African PGMs industry.	What are your feelings about South Africa's education and innovation strategies to build innovative capabilities? What can be done to improve the impact of these strategies to diversify the PGMs industry?	Are the strategies focussed on objectives?
4	Proposition 4: South Africa's PGMs product space network density is likely to sustain the diversification and expansion of current PGMs-related products.	What is your feeling about the relationship between products manufactured in South Africa and its PGMs endowment? What is required to increase the relatedness of capabilities in the South African PGMs value chain?	
5	Proposition 5: FDI will likely cause the South African PGMs industry to diversify into manufacturing and export of finished PGMs products.	How do you feel about outward FDI impacts on knowledge creation and innovation in SA PGMS industry? How do you feel about inward FDI impacts on knowledge creation and innovation in SA PGMS industry?	According to you which one is preferable and why? If both are preferable why?