JOURNAL OF DEVELOPMENT ECONOMICS AND FINANCE
Vol. 5, No. 1, 2024, pp. 39-66

URL : www.arfjournals.com
https://DOI:10.47509/JDEF.2024.v05i01.03

An Optimisation of Zambia's Manufacturing Finance Model based on Newly Industrialised Country Experiences

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Article History

Received : 28 January 2024

Revised : 20 February 2024

Accepted : 03 March 2024

Published : 27 June 2024

To cite this article

Ng'ambi Wiza, Bupe Getrude Mwanza & Lubinda Haabazoka (2024). An Optimisation of Zambia's Manufacturing Finance Model based on Newly Industrialised Country Experiences. *Journal of Development Economics and Finance,* Vol. 5, No. 1, pp. 39-66. https://DOI:10.47509/JDEF.2023.v05i01.03

Abstract: This study attempts to optimise Zambia's manufacturing finance based on Newly Industrialised Country experiences to generate quantitative non-dominated policy options along with their output targets and quantified instruments. It applies multi-objective particle swarm optimisation with crowding distance on four manufacturing finance models, namely; access to working capital finance, access to investment finance, domestic private start-up investment and foreign private start-up investment. Holding exogenous factors such as manufacturing output constant, the study finds that Zambia's prevailing manufacturing finance is below its potential. This implies that a reconfiguration on the input side may yield better outcomes, with positive ramifications on manufacturing development. The study makes a wholistic set of recommendations, including, promotion of innovation hubs; conglomeration and large firm formation; promotion of technological adoption and facilitating base research and development; increasing education and health funding and enforcing work health and safety regulations; strengthening institutional transparency and accountability; promoting firm financial literacy; incentivising financial sector coverage; and incentivising resource-based manufacturing industries. The study makes two contributions. It pioneers a novel approach to manufacturing finance policy generation in which policy makers are given numerous non-dominated quantified policy options. Secondly, it offers a customisable optimised manufacturing finance model on which policy simulations may be conducted.

Keywords: Manufacturing, finance, policy, optimisation, Zambia, Newly Industrialised Countries

Subject Classification Codes: P52, O14, O16

1. Introduction

"Ranges are for cattle – give me a number" is a popular apocryphal tale by US president Lyndon Johnson about warning policy maker patience with imprecise policy recommendations (Alm, 2017, p. 2). The tale is not from without, policy recommendations from policy learning literature tend to be significantly vague (Alm, 2017; Manski, 2011; Peters, 2020). Extant policy learning literature on manufacturing finance and development such as (Chansa *et al.* (2019), El-haddad (2010), Lee (2019), Mendes *et al.* (2014), Mudenda (2009), Rodrik (2009), Romana and Leonardo (2014) and Weiss (2005) appear to offer recommendations in form of qualitative objectives of the outcome variable encircled with the preferred direction of the determining factors. Three pitfalls are immediately apparent in this practice based on policy analysis literature by Alm (2017) and Manski (2011). Firstly, the narrow recommendation frameworks ignore the significance of cost-benefit analyses in policy selection. Secondly, precision in outcome assessment from policy implementation is lost as recommendations are typically given for non-dynamic settings. Lastly, assumption-linked recommendations tend to have limited shelf life and utility owing to the dynamism of economic phenomena. Zambian manufacturing policy learning literature such as Chansa *et al.* (2019), Chitonge (2016), Fessehaie *et al.* (2015), Mudenda (2009), Mulimbika and Karim (2018) and Yamfwa *et al.* (2002) suffers from the same deficiencies. Such deficiencies exacerbate the already fragile uptake of recommendations by policy makers as a consequence of inefficient political interests. In any case, the deficiencies render policy recommendations inferior to policy maker housed general equilibrium models that address economic dynamics quantitatively.

This study attempts to optimise Zambia's manufacturing finance based on Newly Industrialised Country (NIC) experiences to generate quantitative non-dominated policy options along with their output targets and quantified instruments. It generates a set of non-dominated solutions that combine inputs to generate the outputs of four dimensions of manufacturing finance, namely, access to working capital finance, access to investment finance, domestic private start-up investment and foreign private start-up investment. It extends work by Chansa *et al.* (2019), Lee (2019) and Ng'ambi *et al.* (n.d.). The study makes two main contributions to literature. Firstly, it pioneers a novel approach to manufacturing finance policy generation in which policy makers are given numerous non-dominated quantified policy options. This approach allows policy makers to accurately weigh the costs and benefits of competing policy options. Despite the plethora of NIC policy learning literature, rarely are concrete policy recommendations offered beyond generic statements about what needs to be done. Secondly, it offers a customisable optimised manufacturing finance model on which policy simulations may be conducted. Because literature tends to provide assumption-linked recommendations, the dynamic nature of economic phenomena limits their shelf life and utility as policy makers are unable to ascertain the quantitative implications of assumption changes. In this view, a customisable model allows real time adjustment and assessment of recommendations as conditions evolve.

2. Literature Review

Chansa *et al.* (2019) presented a comparative study of the industrial development of Zambia and South Korea. The industrial policy focused study conceptualised that while Zambia did not implement the actions requisite of a developmental state, South Korea's evolution into a developmental state led to its industrialisation. Further, Chitonge (2016) and Yamfwa *et al.* (2002) find productivity gaps in Zambia's structural transformation with Yamfwa *et al.* (2002) noting implementation inefficiencies during the import substitution industrialisation and market liberalisation phases, conclusions shared with Mudenda (2009), Rolfe and Woodward (2004) and Thurlow and Wobst (2006). Furthermore, Lombe (2018), Fessehaie *et al.* (2015), Seidman (1974) and Mulimbika and Karim (2018) highlight an inconducive financial sector for industrialisation in Zambia. Mendes *et al.* (2014) noting that import substitution industrialization in SSA followed the Latin American blueprint, argue that import substitution industrialisation failed due to low domestic savings and capital stock, low quality of labour, and declining terms of trade (see also Gui-Diby and Renard (2015)). They argue that the foregoing constellated into a paradoxical increase of Africa's dependence on developed countries instead of a decrease. Seidman (1974) makes an identical case for then Zambia's dualist economy (see also Kapunda (2005) on the overemphasis and misapplication of comparative advantage).

In view of the foregoing, Chansa *et al.* (2019) summarise seven sources of Zambia's divergence from the South Korean model, namely, (1) weak transition from import substitution industrialisation, (2) low progression up the manufacturing value chain, (3) poor proximity to international trade hubs, (4) weaker investment in human capital development, (5) externally oriented FDI,

(6) poor State precision in private sector intervention and (7) macroeconomic instability and policy inconsistency. To remedy the divergence the study notes the significance of State-private interaction in industrial policy design, arguing for institutional accountability and transparency, along with systematic incentive and monitoring frameworks. With regard to industrial sector policy formulation the study makes six key recommendations: (1) use of comparative advantage to identify the sectors to support, (2) incentivising firms towards selected activities enclosed in structured monitoring frameworks, (3) State-private partnerships in nascent stages of difficult investments, (4) providing technical and financial support to SMEs, (5) facilitating research and development and incentivising technology transfer from foreign investment and (6) continuous institutional capacity strengthening through international learning missions.

With a broader African scope, Lee (2019)used specific cases of industrial firms and sectors in South Korea to draw comparison and lessons for African countries and found that financing industrialisation through state-controlled institutions played a critical role in South Korea. Specifically, the study argued that the supply of growth financing at affordable rates to priority sectors, of which manufacturing received special focus, accelerated South Korean industrialisation. The study found such effective industrialisation structures deficient in African countries, conclusions shared with Chansa *et al.* (2019), Romana and Leonardo (2014) and Weiss (2005). El-haddad (2010) in the specific case of Egypt also notes divergent industrialisation outcomes in favour of South Korea; arguing that while South Korean policy and strong institutions successfully harnessed key sources of finance and forged it on a self-financing path, Egypt failed to provide finance for sustained industrialisation. Yusuf (2014), Seidman (1974), Rodrik (2009) and Egbetunde *et al.* (2017) however find institutions and policy implementation in Africa weak relative to NICs. While noting the diversity of African countries, Lee (2019) makes several Korean experience inspired recommendations on financing industrial development, including, (1) some state control on credit allocation, (2) direct State intervention through SOEs on critical but hard to invest projects and (3) facilitating research and development.

Besides policy and institutional strength, numerous financial sector factors may inhibit manufacturing finance policy implementation. Beck and Demirguc-Kunt (2013) study financial structure and access to finance and find that the dominance of banks is associated with lesser financial service utilisation and poor financial services, additionally noting that specialised lenders enhance service in low-income countries. This expectedly inhibits actualisation of manufacturing finance policy in countries with bank dominated financial sectors like Zambia. Financial sector development is also significant. Guiso *et al.* (2002) find that local financial market development is important in financially integrated markets, noting that while larger firms will increasingly become indifferent to local financial development, small firms will rely on it as financial integration increases. With a backdrop of SMEs (less than 20 employees) accounting for 39 percent of Zambia's manufacturing sector (World Bank, 2021), local financial development becomes significant to manufacturing finance policy.

The channels through which manufacturing finance policy is implemented are also significant. Ma and Lin (2016) investigated monetary policy effectiveness and financial development in 41 economies and found a strong negative relationship between financial development and monetary policy effects on output and inflation (see also Boyd *et al.* (2001) for the negative relationship between financial sector allocative efficiency and inflation). Fernald *et al.* (2014) and Chuku (2009) also found evidence of monetary policy effects on real sector performance and price. Georgiadis and Mehl (2016) further contextualised monetary policy effectiveness in financial globalisation and found that net long foreign currency economies experience stronger monetary effects through external balance sheet valuation losses and wealth effects due to exchange rate gains through tight monetary policy. As noted by the Financial Sector Development Policy, financial sector underdevelopment in Zambia is a major cause of monetary policy ineffectiveness (GRZ, 2017), as such, manufacturing finance policy implementation needs to either strengthen the monetary policy transmission channels or pursue more direct interventions.

Fiscal policy as shown in the case of South Korea can be a significant source of manufacturing finance. Ehigiamusoe and Lean (2020) found that the positive effects of financial development on growth relied on public debt and deficit levels lying within stipulated thresholds. Zambia's nagging public debt may thus prove detrimental to manufacturing finance policy implementation. Further, foreign financial inflows need consideration. Benmamoun and Lehnert (2013) compared the effectiveness of FDI, aid and remittances on growth and found that international remittances had the greatest effect even in FDI reliant countries. This is especially noteworthy given Zambia's overemphasis on FDI for manufacturing finance resources (Bwalya, 2006; Gui-Diby & Renard, 2015; Haglund, 2008).

With regard to aid, Rajan and Subramanian (2011) investigate the effects of aid on manufacturing growth and conclude that aid has adverse effects on manufacturing growth because it over appreciates the exchange rate and recommend that countries should prevent situations that lead to uncompetitive exchange rates (see also GRZ (2014) for the negative effects of exchange rate over appreciation on manufacturing in Zambia). Tsaurai (2018) introduced financial development to the discussion and found that the complementarity effects between aid and financial development had a positive impact on economic growth. In Zambia, Inanga and Mandah (2008) found that while isolative, aid effects when efficiently and effectively applied positively contribute to growth in stable macroeconomic environments. Prasad and Nickow (2016) however recount the aid histories of South Korea and Pakistan and argue that; aid promotes corruption, overwhelms administrative capacity and weakens tax systems. Further, Asongu (2015) reviews 53 African countries and concludes that institutional quality plays a significant role on the growth effects of aid. Besides supply side factors, as shown by a plethora of literature, demand side factors in the form of manufacturing firm characteristics play a significant role in the utilisation of manufacturing finance (Das, 2015; Fowowe, 2017; Mertzanis, 2016; Musamali & Tarus, 2013; Wasiuzzaman *et al.*, 2020).

Chansa *et al.* (2019) and Lee (2019), on which this study is partly based while helpful in giving context, do not appear to provide sufficiently actionable recommendations. In this view, this study borrows the modelling of Zambia's manufacturing finance presented in Ng'ambi *et al.* (n.d.) with a view to generate quantitative policy options, complete with output targets and quantitatively specified instruments. Ng'ambi *et al.* (n.d.) model Zambia's manufacturing finance in four equations: access to working capital finance, access to investment finance, domestic private start-up investment and foreign private start-up investment. The study applies Structural Equation Modelling on a merged micro and macro dataset encompassing: World Bank Enterprise Surveys, World Development Indicators, International Finance Statistics and complementary data from Central Banks and Ministries of Finance. It also builds on NIC experiences by modelling NICs and Zambian manufacturing finance simultaneously to establish the differences and similarities with a view to ascertain which manufacturing finance policy instruments from the NICs would have the same effect in the Zambian case. The current study adopts external econometric models purely for the convenience of managing article pagination, the ensuing methodology can thus be applied on differently sourced or own-generated but well-defined and robust manufacturing finance econometric models.

3. Methodology

A multi-objective optimisation attempts to generate a pareto front of non-dominated solutions based on trade-off solutions between competing and sometimes conflicting objectives (Briza & Naval, 2011; Raquel & Naval, 2005). A solution is non-dominated if an improvement in one aspect requires worsening at least one other aspect. Such optimisations aim to obtain the best estimate of the pareto optimal set that is well distributed. Algebraically, a multi-objective optimisation problem may be stated as follows (Briza & Naval, 2011);

Maximise: $y = f(x) = (f_1(x),\ldots, fn(x))$

Subject to: $g(x) = (g1(x),\ldots, gn(x)) \leq 0$ and $h(x) = (h_1(x), \ldots, h_n(x)) = 0$

Where; $x = (x_1, \ldots, x_m) \in X$ and $y = (y_1, \ldots, y_n) \in Y$

Such that x is a decision vector with X as its decision space, and y is the objective vector with Y as its objective space with $g(x)$ and $h(x)$ being the constraints. In this way, a solution (pareto front), x^* are decision vectors that optimise the objective functions.

The study applied multi-objective particle swarm optimisation with crowding distance. Attributed to Kennedy and Eberhart (1995), particle swarm optimisation is an optimisation algorithm based on the social behaviour of a swarm of birds as they search for food. With little practical use from the social metaphor, optimisation is achieved by firstly launching an initial population of particles with random solutions in the solution search space. For every generation, each particle maintains its best solution and its so far found global best solution, updating this relative to the other particles. The search direction is further updated based on the particle and global best solutions; iteration of the foregoing thus generates a collection of non-dominated solutions. Among heuristic optimisation methods, MOPSO was selected because it stood to provide the most optimal outcomes for the study. Specifically, relative to other heuristics, PSO carries two key advantages, its relative simplicity and effectiveness at low computational cost (Briza & Naval, 2011; Hassan *et al.*, 2005; Raquel & Naval, 2005). The study applied MOPSO with Crowding Distance (MOPSOCD), a MOPSO variation that incorporates the Non-Dominated Sorting Genetic Algorithm (NSGA-II, an evolutionary algorithm) crowding distance density estimator to facilitate global best selection and removal of less optimal but non-dominated solutions from the archive. The MOPSOCD pseudo code and algorithm flow chart found in Briza and Naval (2011, pp. 1193–1194) are reproduced below.

*"**Begin***
Initialise swarm;
Evaluate objective functions;
Store particle bests;
Store non-dominated particles;
As 0 approaches time, t;
***While** time, t is less than the maximum time,* t_{max}
Compute crowding distances in the archive and select guides;
Compute new positions;
Mutation;
Evaluate objective functions;
Impose constraints;
Update archive;
Update particle bests;
As time plus one, t +1 approaches t;
End while
***End**"*

Where, P, M, A, P_i, and V_i are the population, population size, external archive, position of the i^{th} particle and velocity of the i^{th} particle, respectively. With *[a]*, the velocity update equation given by:

$$V_i = w * V_i + R1 * (pbest_i - P_i) + R2 * A_{gbest} - P_i$$

Where, w, $r1$ and $r2$, $pbest_i$, A_{gbest} are inertia weight, random numbers in the range [0…1], best position that particle i have reached and global best guide for each non-dominated solution, respectively. Further, *[b],* the position update equation is given by:

$$P_i = P_i + V_i$$

The study adopted heuristic optimisation as opposed to classical econometric optimisation methods such as linear programming. Based on Gilli and Schumann (2012) and Krink and Paterlini (2011), heuristic optimisation carried numerous

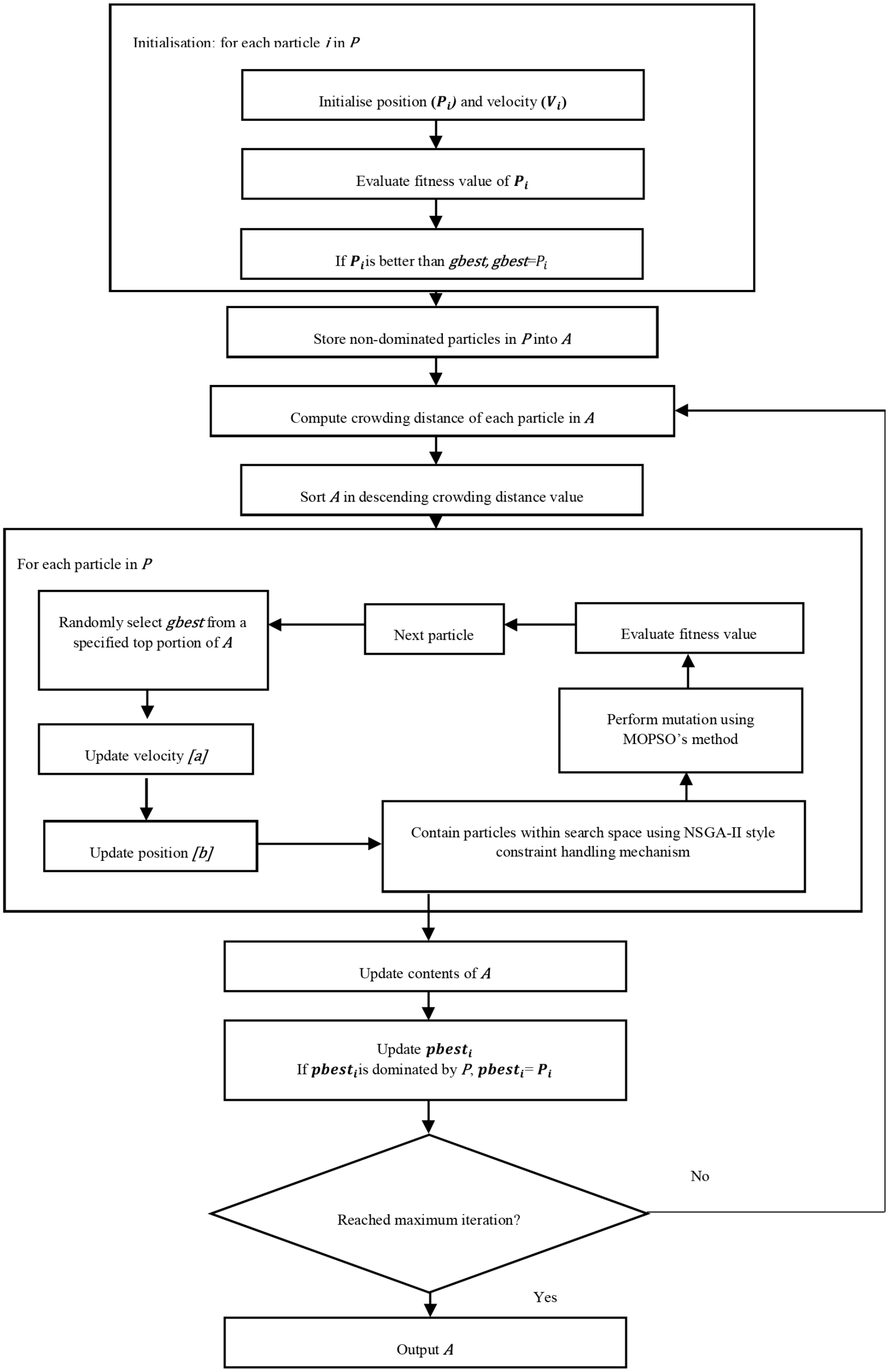

Figure 1: Multi-Objective Particle Swarm Optimisation with Crowding Distance Algorithm

advantages over linear programming in the current study. Firstly, heuristic optimisation allowed application of more diverse constraints relative to linear programming. With a multiplicity of objective functions, variables and constraints, heuristic optimisation allows easier application of constraints. Secondly, heuristic optimisation executes faster than linear programming, with multiple iterations and corrections, linear programming takes longer to implement.

The study implemented MOPSOCD using the *mopsocd* package in R. As the optimisation was based on a heuristic method, robustness checks focused on using alternative algorithms to ensure that the generated optimums were substantiated by other algorithms. This methodology was applied on six Zambian objective manufacturing finance equations obtained from (Ng'ambi et. al, forthcoming), using constraints generated from the World Bank Enterprise Survey and World Development Indicators datasets. The constraint framework adopted the thresholds of historical Zambian performance such that it is not outside the scope of reason that such limits can be attained. Other operational constraints were placed on the optimisation to ensure that the optimal solutions conformed to economic logic such as keeping ownership share between 0 and 100.

4. Results

This section highlights the optimisation equations, states the constraints and benchmarks the non-dominated solutions against the respective performances of South Korea, NICs and Zambia.

4.1. Optimisation Equations

The four optimisation equations highlight how manufacturing finance relates to its determinants in the Zambian case. Optimising these equations stands to yield optimal manufacturing outcomes given Zambia's prevailing conditions in terms of both capabilities given previous performance and interrelationships among the associated variables. Knowledge of these specific solutions and the input variable levels needed to achieve them may give policy makers specific policy options from which to select, complete with targets and instruments on both the input and output sides.

(a) Access to working capital finance (AWC)

$$AWC = 13.574 + 14.556FT + 12.338TC - 0.018NW + 0.012AS$$

The equation above shows the access to working capital finance equation. It shows that, on average, a limited liability companies (FT) have about 15 percentage points higher access to working capital finance with firms reporting taxation constraints (TC) having about 12 percentage points higher access to working capital finance. Further, an extra worker (NW) is associated with 0.02 percentage points lower access to working capital finance while an extra million in sales (AS) increases access to working capital finance by about 0.01 percentage points.

(b) Access to investment finance (AIN)

$$AIN = 5.171 + 18.815FA - 0.126CU + 5.736CP$$

The above equation shows the access to investment finance equation. It shows that, on average, firms that had fixed assets (FA) had about 19 percentage points more access to investment finance. Further, a percentage point increase in capacity utilisation (CU) reduced access to investment finance by about 0.13 percentage points. Lastly, a million increase in the population (CP) of the firm's host city was associated with a 6-percentage point increase in the firm's access to investment finance.

(c) Domestic private ownership (DPO)

$$DPO = 336.12 + 0.19ODA + 0.09IWC - 1.15MVA - 5.89FT - 0.13NW - 2.14LFP - 9.6TI$$

The above equation shows the domestic private ownership equation. It shows that, on average, an additional foreign aid (ODA) dollar increased domestic private start-up investment by 0.19 percentage points, and in the same way, firms that were inclined to finance working capital internally (IWC) were associated with higher domestic private start-up investment. On the contrary, a dollar increase in MVA per capita reduced domestic investment by 1.15 percentage points. Similarly, limited liability companies (FT) were associated with 5.89 percentage points less domestic private start-up investment. Further, an extra worker (NW) reduced domestic private start-up investment by 0.13 percentage points and a percentage point increase in the labour force participation rate (LFP) reduced domestic private start-up investment by 2.14 percentage points. Lastly, a unit increase in technology intensity (TI) reduced domestic private start-up investment by 9.6 percentage points.

(d) Foreign private ownership (DPO)

$$FPO = -69.57 - 0.2ODA + 0.91MVA + 8.657FT + 0.12NW + 0.9UR + 0.03H + 8.3TI$$

The above equation shows the foreign private ownership equation. It shows that, on average, an extra foreign aid (ODA) dollar decreased foreign private start-up investment by 0.2 percentage points while a dollar increase in manufacturing output (MVA) increased foreign private start-up investment by 0.91 percentage points. Further, limited liability (FT) firms were associated with 8.66 percentage points higher foreign private start-up investment with an extra worker associated with a 0.12 percentage point increase in foreign private start-up investment. Furthermore, an increase in the unemployment rate (UR) raised foreign private start-up investment by 0.9 percentage points, a percentage point increase in imported inputs (II) was associated with a 0.03 percentage point increase in foreign private start-up investment and a unit increase in technology intensity (TI) raised foreign private start-up investment by 8.3 percentage points.

4.2. Optimisation Constraints

Table 1 below presents the constraints placed on the optimisation. As the optimisation was on the Zambian system, the constraints were drawn from the values that have previously prevailed in the Zambian case so that it is not out of the scope of reason that they are attainable. Other constraints include mathematical constraints (omitted for leaner exposition) to align the results to all the equations generated by the SEM models as well as consistency restrictions aimed at keeping results in economically sound limits, e.g., ownership share lying between 0 and 100 percent.

Table I: Optimisation Constraints

S/n	*Type*	*Variables*	*Minimum*	*Maximum*
1	Input	ODA per capita	1	234
2	Input	Internal working capital	0	100
3	Input	MVA per capita	97	118
4	Input	Firm type	0	1
5	Input	Number of workers	1	2500
7	Input	Labour force participation	73	80
8	Input	Technology intensity	1	4
9	Input	Unemployment rate	7	20
10	Input	Imported inputs	0	100
11	Input	Taxation constraints	0	1
12	Input	Annual sales	0.02	3000
13	Input	Fixed assets	0	1

14	Input	Capacity utilisation	2	100
15	Input	City population	0.1	4
16	Output	Access to working capital finance	0	100
17	Output	Access to investment finance	0	100
18	Output	Domestic private ownership	0	100
19	Output	Foreign private ownership	0	100

4.3. Non-Dominated Solutions

3,261 non-dominated solutions were generated from maximising the multi-objective equations subject to their constraints. As stated above, a fair amount of value judgement is needed to select the appropriate policy targets from the non-dominated solutions. Considerations include prevailing policy priorities, the implementation costs and benefits and a priori benchmarks. In this section, the latter consideration is made using the South Korea, NICs and Zambian average as benchmarks, considering solutions that were at least as good or at least as close to the benchmarks in terms of access to finance and start-up investment finance, excluding extreme cases while ensuring manufacturing value added per capita remained within 1 percent of the highest historical value.

Of the 3,261 non-dominated solutions, as shown in table 2 below, 6 satisfied the South Korean benchmark allowing for up to 25 percent less domestic private ownership. Further, 5 satisfied the South Korean benchmark allowing for up to 25 percent less domestic private ownership as shown in table 3 below, all of which also satisfied the South Korean benchmark. Lastly, as shown in table 4 below, 9 solutions satisfied the 2019 Zambia benchmark allowing for up to 10 percent less domestic private ownership., three of which appeared under both the South Korean and NICs benchmarks.

While it is emphasised that ultimate policy direction should consider the non-dominated solutions that most align with the extant policy priority framework, which expectedly changes relatively frequently, two statistical frameworks are arbitrarily adopted here to assess the veracity of the generated solutions. Firstly, the solution statistically closest to the 2019 actualised performance on the input side (here on, statistically least effort optimal solution), and secondly the three common solutions across the three benchmarks (here on, three common benchmark solutions). The former adopts the solution with the minimum sum of the squared differences between the 2019 performance inputs and the inputs of each of the 17 benchmark solutions. This is presented in table 5 below.

Table II: Optimisation Benchmark: South Korea

Solution no.	*351*	*1469*	*2103*	*2552*	*2779*	*2848*
ODA per capita	101.5	162.4	150.9	143.2	116.7	190.3
Internal working capital	72.6	59.1	79.1	65.5	57.7	73.4
MVA per capita	101.0	102.4	102.7	101.2	102.3	101.8
Firm type	0.7	0.8	0.9	0.7	0.7	0.6
Number of workers	20	34	120	73	132	66
Labour force participation	76.3	76.2	76.5	76.2	75.3	76.8
Technology intensity	3.3	1.6	2.0	2.6	2.3	1.8
Unemployment rate	16.8	16.5	17.2	17.1	16.6	17.2
Imported inputs	30.0	37.4	26.3	32.4	32.0	56.3
Taxation constraints	0.7	0.8	0.6	0.9	0.8	0.8
Annual sales	2862.4	2917.5	2916.3	2949.6	2980.0	2989.7
Fixed assets	0.6	0.7	0.7	0.6	0.6	0.7
Capacity utilisation	36.3	16.1	14.1	40.6	9.3	18.1
City population	0.9	2.0	2.6	1.0	1.8	2.4
Domestic private ownership	66.8	70.7	67.0	69.0	67.2	67.1
Foreign private ownership	18.0	28.7	31.3	16.7	24.7	30.8
Access to working capital finance	44.1	67.3	50.3	52.6	41.9	68.5
Access to investment finance	55.8	32.1	49.5	46.6	57.7	30.9

Table III: Optimisation benchmark: NICs

Solution no.	*1469*	*2103*	*2552*	*2779*	*2848*
ODA per capita	162.4	150.9	143.2	116.7	190.3
Internal working capital	59.1	79.1	65.5	57.7	73.4
MVA per capita	102.4	102.7	101.2	102.3	101.8
Firm type	0.8	0.9	0.7	0.7	0.6
Number of workers	34	120	73	132	66
Labour force participation	76.2	76.5	76.2	75.3	76.8
Technology intensity	1.6	2.0	2.6	2.3	1.8
Unemployment rate	16.5	17.2	17.1	16.6	17.2
Imported inputs	37.4	26.3	32.4	32.0	56.3
Taxation constraints	0.8	0.6	0.9	0.8	0.8
Annual sales	2917.5	2916.3	2949.6	2980.0	2989.7
Fixed assets	0.7	0.7	0.6	0.6	0.7
Capacity utilisation	16.1	14.1	40.6	9.3	18.1
City population	2.0	2.6	1.0	1.8	2.4
Domestic private ownership	70.7	67.0	69.0	67.2	67.1
Foreign private ownership	28.7	31.3	16.7	24.7	30.8
Access to working capital finance	67.3	50.3	52.6	41.9	68.5
Access to investment finance	32.1	49.5	46.6	57.7	30.9

Table IV: Optimisation benchmark: 2019 Zambian

Solution no.	*1469*	*1886*	*1989*	*2103*	*2268*	*2848*	*3258*	*4016*	*4488*
ODA per capita	162.4	149.8	160.3	150.9	120.3	190.3	62.2	109.0	221.4
Internal working capital	59.1	65.6	67.1	79.1	70.3	73.4	79.2	69.5	57.4
MVA per capita	102.4	101.3	101.2	102.7	102.0	101.8	101.4	102.5	101.9
Firm type	0.8	0.7	0.9	0.9	0.7	0.6	0.9	0.6	0.9
Number of workers	34	143	74	120	108	66	135	8	25
Labour force participation	76.2	76.0	76.0	76.5	76.5	76.8	76.8	77.0	76.6
Technology intensity	1.6	1.8	3.3	2.0	1.4	1.8	2.4	2.1	1.4
Unemployment rate	16.5	17.2	17.0	17.2	17.3	17.2	17.5	17.6	17.5
Imported inputs	37.4	37.7	31.5	26.3	35.3	56.3	24.2	48.7	40.1
Taxation constraints	0.8	0.9	0.6	0.6	0.7	0.8	0.7	0.9	0.7
Annual sales	2917.5	2921.4	2744.2	2916.3	2977.9	2989.7	2866.0	2831.7	2598.7
Fixed assets	0.7	0.6	0.8	0.7	0.7	0.7	0.9	0.8	0.8
Capacity utilisation	16.1	27.3	26.5	14.1	14.5	18.1	19.3	28.1	21.3
City population	2.0	2.3	2.4	2.6	1.5	2.4	1.4	2.8	2.6
Domestic private ownership	70.7	66.4	66.4	67.0	66.1	67.1	66.4	66.5	66.2
Foreign private ownership	28.7	26.5	31.6	31.3	25.8	30.8	27.0	33.4	31.6
Access to working capital finance	67.3	52.3	47.9	50.3	53.5	68.5	28.4	56.7	81.7
Access to investment finance	32.1	47.3	51.8	49.5	46.2	30.9	71.4	43.0	17.9

Table V: Optimisation benchmark: statistically least effort optimal solution

Solution no.	*4488*	*1989*	*4016*	*351*	*2019 Zambia*
Proximity rank	1	2	3	4	
ODA per capita	221.4	160.3	109.0	101.5	55.8
Internal working capital	57.4	67.1	69.5	72.6	80.8
MVA per capita	101.9	101.2	102.5	101.0	101.6
Firm type	0.9	0.9	0.6	0.7	0.2
Number of workers	25.0	74.0	8.0	20.0	70.1
Labour force participation	76.6	76.0	77.0	76.3	74.1
Technology intensity	1.4	3.3	2.1	3.3	1.4
Unemployment rate	17.5	17.0	17.6	16.8	12.4
Imported inputs	40.1	31.5	48.7	30.0	23.4
Taxation constraints	0.7	0.6	0.9	0.7	0.3
Annual sales	2,598.7	2,744.2	2,831.7	2,862.4	34.9
Fixed assets	0.8	0.8	0.8	0.6	48.5

Solution no.	*4488*	*1989*	*4016*	*351*	*2019 Zambia*
Capacity utilisation	21.3	26.5	28.1	36.3	70.1
City population	2.6	2.4	2.8	0.9	0.5
Domestic private ownership	66.2	66.4	66.5	66.8	73.4
Foreign private ownership	31.6	31.6	33.4	18.0	24.8
Access to working capital finance	81.7	47.9	56.7	44.1	16.0
Access to investment finance	17.9	51.8	43.0	55.8	6.9

5. Discussion

5.1. Outputs

Over the study period, the actualised weighted average access to working capital finance had a maximum of 29.96 percent and a minimum of 15.9 percent while the 2019 performance stood at 15.99 percent. The statistically least effort optimal solution had 81.7 percent while the three common benchmark solutions had a maximum of 68.5 percent and minimum of 50.3 percent. Further, the actualised weighted average access to investment finance over the study period had a maximum of 7.4 percent and a minimum of 6.3 percent while the 2019 performance stood at 6.9 percent. The statistically least effort optimal solution had 17.9 percent while the three common benchmark solutions had a maximum of 49.5 percent and minimum of 30.9 percent. This implies that Zambia's current performance is below its own potential as reconfiguration, keeping exogenous resources such as the level of manufacturing output constant, would yield better outcomes.

As regards ownership, over the study period, the actualised weighted average domestic private ownership had a maximum of 78.0 percent and a minimum of 71.5 percent while the 2019 performance stood at 73.4 percent. The statistically least effort optimal solution had 66.2 percent while the three common benchmark solutions had a maximum of 70.7 percent and minimum of 67 percent. Further, the actualised weighted average foreign private ownership over the study period had a maximum of 24.8 percent and a minimum of 19.3 percent with the 2019 performance having been the maximum. The statistically least effort optimal solution had 31.6 percent while the three common benchmark solutions had a maximum of 28.7 percent and minimum of 31.3 percent. While higher domestic private ownership is preferred, the price of admission is more domestic financial resources. As shown in the benchmarking and modelling results and extant literature, domestic resources do not appear sufficient in Zambia, as with many

LDCs. Infusion through foreign aid and private investment are thus necessary for more optimal manufacturing finance outcomes. As pointed out by Lee (2019) and Fischer (2018), domestic ownership is preferred to foreign ownership because it stimulates domestic value chains, spurs reinvestment and reduces foreign influence on the domestic market. There is however a trade-off in the case of developing countries for whom domestic resources do not permit higher levels of domestic ownership, as rightly considered by including foreign private ownership and other related factors in this analysis.

5.2. Inputs

Focusing on the inputs. Over the study period, actualised ODA per capita recorded a maximum of USD 234 over the study period and averaged USD 56 in 2019. The statistically least effort optimal solution had USD 221 while the three common benchmark solutions had a maximum of USD 190.32 and minimum of USD 162. Evidently, this study recommends increasing foreign aid into the country to enhance manufacturing finance. Despite some caution on the foreign aid, literature appears conclusive on the potential benefits of foreign aid when applied correctly, more so in relation to manufacturing development. This recommendation is in line with Inanga and Mandah (2008) who based on the study of foreign aid effects on economic development (with special focus on manufacturing) in Zambia conclude that under some conditions, effectively utilised foreign aid finance can generate economic growth. In the same vein but within the broader context of industrialisation, Fischer (2018) argues that aid can partly absorb the trade deficits with which industrial development comes as in the case of South Korean industrialisation. Similar conclusions and recommendations may be found in Benmamoun and Lehnert (2013), Lee (2019), Rajan and Subramanian (2011) and Tsaurai (2018), to mention a few. In practice, foreign aid may be attracted by enhancing institutional transparency and accountability, proactively fighting corruption and increasing funding to the judiciary and law enforcement agencies (Asongu, 2015; Inanga & Mandah, 2008; Prasad & Nickow, 2016; Rajan & Subramanian, 2011). Such aid accumulation may further be channelled through the commercial financial sector to increase its effectiveness, as was the case in South Korea (Lee, 2019).

Over the study period, the actualised weighted average internally financed working capital recorded a maximum of 81 percent and a minimum of 67 percent with 2019 having been the maximum. The statistically least effort optimal solution had 57 percent while the three common benchmark solutions had a maximum of 79 percent and minimum of 59 percent. This study recommends a reduction in internally financing start-ups. While an attractive option, self-financing leads to small and unscalable enterprises that later fail to access external finance. This recommendation is in line with Girma and Vencappa (2014) that argue that external financing leads to higher firm productivity relative to internal financing. The study recommendation is also in line with Ayodeji and Balcioglu (2010) who find that the source of start-up investment affects access to finance and consequently industrialisation. As an alternative, this study proposes use of innovation hubs to ready enterprises for proper financing and scalable launch.

Over the study period, the actualised MVA per capita recorded a maximum of USD 102 and a minimum of USD 84 with 2019 having recorded the maximum. The statistically least effort optimal solution had USD 102 while the three common benchmark solutions had a maximum of USD 103 and minimum of USD 102. By design, the analysis of the non-dominated solutions returned solutions that preserved the highest historical manufacturing sector output. This was implemented to show that higher access to manufacturing finance outcomes were possible at the current level of manufacturing output.

The 2019 and 2013 actualised weighted average share of limited liability companies were 18 percent and 21 percent, respectively. The statistically least effort optimal solution had 90 percent while the three common benchmark solutions had a maximum of 92 percent and minimum of 64 percent. Evidently, the level of formalisation is significantly below the model prescribed levels with expectedly significant ramifications on manufacturing finance. As demonstrated above, formalisation enhances access to manufacturing finance and propagates manufacturing development. This recommendation is in line with Musamali and Tarus (2013), who note the significance of perpetual existence of the firm in access to finance. Similarly, Mertzanis (2016) argues for increased business formalisation to increase access to finance. Such enhancement of firm formalisation in Zambia may be achieved by streamlining formal business registration and the associated compliance requirements as well as attaching higher business formalisation to government enterprise financing.

Over the study period, the actualised number of workers recorded a maximum of 900 workers, while the weighted average number of workers had a maximum of 74 workers and minimum of 32 workers, with 71 workers recorded in 2019. The statistically least effort optimal solution had 25 workers while the three common benchmark solutions had a maximum of 120 workers and minimum of 34 workers. The variation across the optimal solutions on number of workers suggests that numerous firm size options exist, albeit with trade-offs. For instance, the decrease in number of workers from 120 to 25 is associated with a decrease in access to investment finance but an increase in access to working capital. The moderate 66 number of workers appears to produce a more moderate distribution between access to working capital and investment finance. In such situations, policy should then consider other related inputs and assess its priorities given such options.

Over the study period, the actualised labour force participation recorded a maximum of 80 percent with 74 percent recorded in 2019. The statistically least effort optimal solution had 77 percent while the three common benchmark solutions had a maximum of 77 percent and minimum of 77 percent. Labour force participation appears stable across the three solutions and proximal to the actualised values. As in the case of number of workers, policy has leeway to consider other factors as the reference variable can lead to diverging outcomes.

Over the study period, the actualised technology intensity recorded a maximum of level four (high technology industries) featuring Radio, TV and communications equipment, with a weighted average of level one (low technology industries) in 2019, featuring Food, beverages and tobacco. The statistically least effort optimal solution had level one while the three common benchmark solutions had a maximum and minimum of approximately level two (medium-low technology industries). Given the variation among the optimal solutions, preference may appear geared towards higher technology intensity. In the three competing solutions, higher technology intensity appears associated with higher employment, which may imply higher recruitments in more skilled workers and consequently higher wages. The study thus recommends moving up the technology intensity scale. As recommended by Lee (2019), escaping the middle-income trap requires that manufacturing moves up the value chain into producing higher value goods. This evidently requires adoption of more advanced technologies and developing domestic ecosystems for higher value products. This recommendation is also supported by industrial catch-up literature (Chandra *et al.*, 2013; Landini *et al.*, 2017; Lee *et al.*, 2016; Lin *et al.*, 2021; Zhu *et al.*, 2017). In practice, policy may incentivise technology adoption through import tax incentives on desired technological products and facilitate and finance base research that could be latter commercialised.

Over the study period, actualised unemployment rate recorded a maximum of 20 percent over the study period and 12 percent in 2019. The statistically least effort optimal solution had 18 percent while the three common benchmark solutions had a maximum of 17 percent and minimum of 17 percent. Evidently, the optimal solutions appear to lean towards higher unemployment rate than experienced in 2019 but lesser than the highest over the review period. As shown in literature, higher unemployment rate tends to attract foreign investment through the labour availability and lower wages channel (GRZ, 2014; Lee, 2019). Because higher unemployment is undesirable, it may be prudent to pursue policy that preserves the benefits of unemployment without the actual unemployment. This may be achieved by enhancing the quality and quantity of labour available through increasing education and health funding and enforcing work health and safety regulations (BoZ *et al.*, 2019; GRZ, 2014).

Over the study period, the actualised weighted average imported inputs recorded a maximum of 40 percent and a minimum of 23 percent, with the latter recorded in 2019. The statistically least effort optimal solution had 40 percent while the three common benchmark solutions had a maximum of 56 percent and minimum of 26 percent. The optimal solutions appear to lean towards higher imported input shares than experienced in 2019. As shown in analyses such as Fischer (2018) and Lee (2019), the industrialisation transition comes with transitory trade deficits associated with production imports. While this study recommends accommodating such imports, care should be taken to ensure that domestic manufacturing sector building imports are prioritised. As shown by Chansa *et al.* (2019) and Mudenda (2009), Zambia has previously endured the imported input dependence trap where the manufacturing sector's foreign exchange earnings were overwhelmed by its input imports. Policy may thus, where possible, incentivise resource-based manufacturing industries.

Over the study period, the actualised weighted average taxation constraints recorded a maximum of 34 percent and a minimum of 20 percent, with 2019 recording the maximum. The statistically least effort optimal solution had 72 percent while the three common benchmark solutions had a maximum of 84 percent and minimum of 58 percent. The optimal solutions appear to lean to higher taxation constraints reports than experienced in 2019. The interpretation of taxation constraint reports is significant here. A fair amount of friction is expected between manufacturing firm compliance officers and taxation officers as the two have opposing objectives. Specifically, with taxation reducing profit and increasing government revenue, compliance officers would try to reduce the tax paid by the firm while tax officers would try to increase it. Low taxation constraint reports may thus be attributed to the predominance of small firms (less than 20 employees) in 2019, accounting for about 39 percent compared to 24 percent of large firms (greater than 99 employees) (World Bank, 2021). The low taxation constraints may additionally signal weaker financial literacy in firms and their ability to exploit the taxation system to the point of encountering inefficiencies given that in general taxation systems in developing countries are not very efficient (Prasad & Nickow, 2016). The study thus recommends enhancing financial literacy among firms. Notwithstanding the foregoing argument, as argued by Chansa *et al.* (2019), El-haddad (2010), Lee (2019) and Romana and Leonardo (2014), South Korea's enabling tax policy to the manufacturing sector was a key success factor and policy needs to ensure that it deliberately incentivises manufacturing sector investment.

Over the study period, actualised annual sales recorded a maximum of K 1.7 billion with a weighted average of K 35 million in 2019. The statistically least effort optimal solution was K 2.6 billion while the three common benchmark solutions had a maximum of K 2.99 billion and a minimum of K 2.91 billion. Evidently, the optimal solutions are geared towards higher output. As a plethora of literature shows, there exists a positive association between firm output and access to finance (Wasiuzzaman *et al.*, 2020). The predominance of small firms in Zambian manufacturing (World Bank, 2021), significantly affects the overall access to finance, and as in the case of Nigeria (Ayodeji & Balcioglu, 2010), consequently affects industrialisation. This study thus recommends conglomeration, promoting mergers and large firm formation to achieve the effects a big business manufacturing sector structure achieved in South Korea (Lee, 2019).

Over the study period, the actualised weighted average share of firms buying fixed assets recorded a maximum of 49 percent and a minimum of 42 percent, with the maximum recorded in 2019. The statistically least effort optimal solution had 77 percent while the three common benchmark solutions had a maximum of 75 percent and minimum of 69 percent. Evidently, the optimal solutions lean towards higher collateral accumulation for desirable manufacturing finance outcomes. As literature has shown, collateral plays a significant role in financial contracting especially in liquidity constrained financial systems (Amornkitvikai & Harvie, 2017; Beck & Feyen, 2013; Fessehaie *et al.*, 2015; GRZ, 2017; Musamali & Tarus, 2013; Wasiuzzaman *et al.*, 2020). The study thus naturally recommends promotion of firm asset ownership coupled with higher institutional formalisations through fixed asset enabling policies via interest rate and liquidity channels.

Over the study period, the actualised weighted average capacity utilisation recorded a maximum of 70 percent and a minimum of 67 percent, with the maximum recorded in 2019. The statistically least effort optimal solution had 21 percent while the three common benchmark solutions had a maximum of 18 percent and minimum of 14 percent. The interpretation of capacity utilisation is important here, as discussed above, capacity indicates the growth potential from the financier's perspective. Expectedly, lower capacity utilisation is very attractive to financiers as they stand to exploit a mere expansion of an industry tested product (Tyson, 2017; Wasiuzzaman *et al.*, 2020). With the benefits of low capacity utilisation delineated from the low capacity utilisation, this study recommends the establishment of innovation hubs and business support services to enhance the growth orientation of the manufacturing sector. This would have the effect of enhancing growth potential beyond plant size enhancements.

Over the study period, the actualised host city population recorded a maximum of 2.6 million people and averaged 1 million people in 2019. The statistically least effort optimal solution had 2.6 million people while the three common benchmark solutions had a maximum of 2.6 million people and minimum of 2 million people. The interpretation of population is significant here, urbanisation, proxied by population implies better communication and transport infrastructure, bigger market, greater value chain development and higher concentration of financial institutions. Given that population growth is generally stable and predictable, and cannot be affected radically in the short to the medium term, policy may attempt to stimulate the benefits of urbanisation directly. Incentivising financial institutions to cover the unbanked may for instance raise the concentration of financial institutions. This assessment and recommendation are in line with a plethora of literature (Fanta, 2012; GRZ, 2014, 2017; Mertzanis, 2016).

6. Conclusion

This study has shown that beyond generic recommendations about how developing countries can emulate NIC manufacturing finance policy, analysis needs to offer wholistic and quantified policy options to be effective. This approach allows consideration of related policy interests and helps assess the costs and benefits of competing policy options. The study has demonstrated that, holding exogenous factors such as manufacturing output constant, Zambia's prevailing manufacturing finance is below its potential. This implies that a reconfiguration on the input side may yield better outcomes, with positive ramifications on manufacturing development.

As remediation, the study makes a wholistic set of recommendations to optimise the current manufacturing finance system, summarily: promotion of innovation hubs; conglomeration and large firm formation; promotion of technological adoption and facilitating base research and development; increasing education and health funding and enforcing work health and safety regulations; incentivising manufacturing sector investment; promoting fixed asset ownership through financial channels; strengthening institutional transparency and accountability; promoting firm financial literacy; incentivising financial sector coverage; and incentivising resource-based manufacturing industries.

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