

# Application of Structural Equation Modeling in Microeconomic Research in Africa: A Case Study of the Impact of AfCFTA on the Manufacturing Industry in Zambia

Malcolm Shambana, Ephraim Kaangandu Belemu (PhD)

Africa Research University, Lusaka

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## ABSTRACT

African universities conduct substantial research on African economic development challenges, yet many applications rely on statistical methods that may be suboptimal for addressing complex policy questions in which causal relationships operate through multiple, interrelated mechanisms. This paper argues that Structural Equation Modeling (SEM), grounded in Critical Realist ontology, enables African researchers to model complex causal mechanisms, test indirect pathways, account for latent variables, and provide more nuanced policy guidance than traditional statistical methods. The paper grounds this methodological argument in Critical Realism philosophy (Bhaskar, 1978; Sayer, 1992; Archer, 1995), which emphasises generative mechanisms and the stratified nature of social reality. Drawing on this philosophical foundation, the paper develops a comprehensive SEM framework for analysing the impact of the African Continental Free Trade Area (AfCFTA) on Zambia's manufacturing sector, specifying latent constructs for institutional quality, trade policy implementation, and manufacturing competitiveness. The paper concludes that SEM represents an essential methodological tool for African researchers seeking to understand the context-specific, mechanism-dependent nature of economic policy impacts.

**Keywords:** Structural Equation Modeling; Critical Realism; African manufacturing; trade policy; AfCFTA; latent variables; methodological innovation

## INTRODUCTION

African universities conduct substantial research on African economic development challenges, from manufacturing competitiveness to trade integration to poverty reduction. Yet much of this research relies on methodological approaches, particularly Ordinary Least Squares (OLS) regression and Computable General Equilibrium (CGE) modeling, that may not be optimally suited to the complexity of the questions being investigated. When researchers ask "Does trade liberalisation increase manufacturing employment in Zambia?", the binary yes/no answer that emerges from traditional regression analysis masks crucial nuance: trade liberalisation may increase employment in some contexts but not others, depending on institutional quality, infrastructure availability, worker skills, and firm-level characteristics.

Structural Equation Modeling (SEM) constitutes precisely such a tool. SEM enables researchers to test complex causal hypotheses in which effects operate through multiple pathways, to model unobservable (latent) variables through observable indicators, to test both direct and indirect effects, and to examine how effects vary conditional on other variables. Critically, SEM methodology is grounded in philosophical commitments, particularly Critical Realism, that align well with African development concerns. Critical Realism emphasises that social phenomena have underlying generative mechanisms that may not be directly observable but can be identified through appropriate research design and analysis.

This paper advances the argument that African researchers should adopt SEM as a standard methodological tool for addressing complex economic policy questions. The paper proposes a concrete SEM application: modelling the impact of AfCFTA on Zambia's manufacturing sector, specifying latent constructs for institutional quality,

trade policy implementation, and manufacturing competitiveness, developing measurement models for these constructs, and proposing structural equations to test causal pathways and mediation effects.

## **Critical Realism: Philosophical Foundations for Sem**

### **The Case for Critical Realism in African Development Research**

Critical Realism, as formulated by Bhaskar (1978) and developed by subsequent scholars (Sayer, 1992; Archer, 1995), offers a philosophical framework particularly well-suited to African development research. Critical Realism asserts that reality has a stratified structure comprising three levels: the empirical (what we can observe), the actual (what happens when causal mechanisms operate), and the deep (the generative mechanisms and causal powers that underlie observable phenomena). This distinction proves crucial for development research. When researchers observe that countries with strong institutions also have higher manufacturing growth, Critical Realism encourages investigating the deep level: what mechanisms enable institutions to promote manufacturing growth? What institutional features matter most? Under what conditions do these mechanisms activate or remain dormant?

### **Causal Mechanisms and Mediation Pathways**

A core commitment of Critical Realism is that causal explanation must identify underlying mechanisms. A correlation between trade openness and manufacturing growth is not, by itself, a causal explanation. A causal explanation requires identifying the mechanism: does trade openness work by attracting foreign investment? By exposing firms to competitive pressure? By enabling access to intermediate inputs? By providing market opportunities? Traditional regression cannot distinguish between these mechanisms; it produces a single coefficient for "trade openness". SEM, by contrast, can model multiple pathways and test which mechanisms actually operate. This capability proves especially valuable in African development contexts, where policy effects are frequently context-dependent and mechanism-dependent.

### **Latent Variables in Economic Research**

A second Critical Realist insight concerns latent variables, real but unobservable phenomena that manifest through multiple observable indicators. "Infrastructure Development" is a classic example. Infrastructure quality is not directly observable, yet it shapes economic outcomes. We observe institutions through multiple indicators: Road quality, energy supply and logistic costs. Critical Realism recognises that these observable indicators are manifestations of an underlying infrastructure development construct. SEM models this explicitly, testing how well the observable indicators measure the latent construct, and how the latent construct affects outcomes. This represents a fundamental advantage over OLS regression, which must either use a single proxy variable (losing information) or include multiple collinear indicators (creating statistical problems).

## **STRUCTURAL EQUATION MODELING METHODOLOGY**

### **SEM Overview: Five-Stage Analytical Process**

SEM combines elements of path analysis (modeling multiple causal pathways) with confirmatory factor analysis (modeling latent variables through indicators). The typical SEM analysis proceeds through five stages: (1) Conceptualizing the research question and specifying constructs and pathways; (2) Measuring constructs through indicator selection and data collection; (3) Testing the measurement model to assess whether indicators reliably measure constructs; (4) Testing the structural model to assess whether proposed causal relationships hold; (5) Interpreting results in light of theory and policy context. This five-stage process ensures both conceptual clarity and empirical rigor.

### **Advantages Over OLS Regression**

Traditional OLS regression produces point estimates of the relationship between X and Y, assuming linearity, constant effects across the sample, and a simple causal structure. SEM extends OLS in several directions. First,

SEM can model multiple independent variables affecting multiple dependent variables simultaneously, rather than estimating separate equations. Second, SEM can model indirect effects: paths where X affects Z which then affects Y. Third, SEM explicitly models measurement error, whereas OLS implicitly assumes perfect measurement. Fourth, SEM can test moderating relationships: whether the effect of X on Y depends on the level of Z. These extensions prove particularly valuable when analysing complex policy questions where effects operate through multiple channels and depend on context.

### Comparison with Computable General Equilibrium Models

Computable General Equilibrium (CGE) models represent an alternative method for analyzing complex economic relationships. CGE models use input-output data and behavioral assumptions to simulate economy-wide impacts of policy changes. CGE's strength lies in its economy-wide perspective: it can capture indirect effects as policy shocks ripple through supply chains and factor markets. CGE's weakness lies in its heavy reliance on assumptions: assumptions about factor substitution elasticities, household preferences, market structure, and behavioral responses. When these assumptions are wrong, CGE results can be dramatically incorrect. SEM offers a complementary approach: whereas CGE asks "If we implement this policy under these assumptions, what happens economy-wide?", SEM asks "What mechanisms connect this policy to outcomes, and how strong are these mechanisms in the actual empirical data?"

### Proposed Sem Framework: Afcfta Impact on Zambian Manufacturing

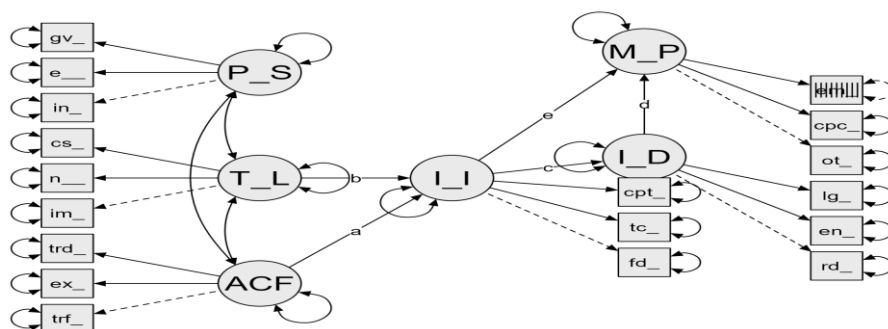
#### Research Question and Theoretical Framework

The overarching research question is: Through what mechanisms and under what conditions does AfCFTA implementation affect manufacturing competitiveness in Zambia? The theoretical framework posits that AfCFTA affects manufacturing through three primary pathways. First, the market expansion pathway: AfCFTA increases market size accessible to firms without tariff barriers, enabling firms to achieve economies of scale and specialise. Second, the institutional pathway: AfCFTA implementation requires harmonising standards, strengthening property rights, and improving business environment quality. Third, the capability pathway: AfCFTA integration exposes Zambian firms to regional and continental competition, pressuring them to improve productivity, invest in technology, and upgrade worker skills.

#### Latent Constructs and Measurement Models

Six latent constructs are central to the proposed framework. First, AfCFTA Integration (ACF) : measured through indicators including: Tariff reduction, Export Access, and Trade Volume. Second, Trade Liberalization (TL): measured through Import regulation, Non-tariff barriers, custom efficiency. Third, Investment Inflow (II), Measure through foreign direct investment, technology transfer, and capital investment. Fourth, Infrastructure Development (ID), measured through road quality, energy supply and logistic cost. Fifth, Manufacturing Productivity (MP), measured through output growth, capacity utilization and employment level. Sixth, Policy Support (PS), measure through industrial policy, ease of business and government incentives.

#### Proposed Structural Model



## **Implications for African Research Institutions**

### **Methodological Capacity-Building**

African universities should prioritise SEM training for postgraduate researchers and faculty. SEM methodology is taught in advanced econometrics courses at leading universities globally; African universities should ensure that PhD and Master's programmes include SEM components. Training should cover not only technical details (software usage, model specification, interpretation) but also philosophical foundations (why Critical Realism matters for development research, what constitutes a good SEM analysis, when SEM is and isn't appropriate).

### **Data Infrastructure**

Effective SEM applications require good data. African development research is constrained by data limitations: many policy effects are observable only through household surveys or firm surveys, which are expensive and often incomplete. African research institutions should work with national statistical offices and international organisations to improve data availability. Specifically, longitudinal data (following the same firms or households over time) would enable stronger causal inference. Similarly, administrative data (trade data, tax data, regulatory data) should be made available to researchers under appropriate confidentiality protections.

### **Policy-Researcher Collaboration**

Closer collaboration between researchers and policymakers, structured appropriately, could benefit both. When policymakers involve researchers early in policy design, research questions can be specified to inform actual decisions. When researchers engage with policymakers, research outputs can be shaped for policy relevance. SEM applications should be presented to policymakers not merely as technical exercises but as providing substantive insights into "what works under what conditions," the type of nuanced guidance that policy design requires.

### **Limitation of Sem**

While Structural Equation Modeling (SEM) offers significant advantages in analysing complex relationships among variables, it is not without limitations. One of the primary challenges of SEM is its reliance on large sample sizes, as small samples can lead to unstable parameter estimates and reduced statistical power. In many African research contexts, obtaining sufficiently large and high-quality datasets can be difficult, which may constrain the effective application of SEM. Additionally, SEM is highly sensitive to model specification; incorrect theoretical assumptions or poorly defined constructs can result in model misspecification and misleading conclusions. The technique also requires advanced statistical expertise, which may limit its adoption among researchers who are more familiar with traditional methods. Furthermore, SEM often assumes linear relationships among variables and may not adequately capture non-linear dynamics unless specifically modeled. Another limitation is the dependence on goodness-of-fit indices, which, while useful, can sometimes lead researchers to prioritize statistical fit over theoretical validity. Consequently, although SEM is a powerful analytical tool, its effectiveness depends heavily on sound theoretical grounding, data quality, and methodological rigor.

## **CONCLUSIONS AND RECOMMENDATIONS**

### **Key Findings**

This paper has established four key points. First, Critical Realism provides a philosophical foundation well-suited to African development research, emphasizing causal mechanisms and context-dependent effects. Second, Structural Equation Modeling operationalizes Critical Realist commitments, enabling researchers to model complex causal structures, latent variables, and mechanism-based explanations. Third, SEM offers methodological advantages over traditional approaches for addressing the types of complex policy questions that African development research addresses. Fourth, African institutions have both the capacity and the imperative to adopt SEM as a standard research methodology.

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## RECOMMENDATIONS FOR ACTION

For African Universities: Include SEM in PhD and Master's curricula; establish SEM research clusters; provide ongoing faculty development; create partnerships with international institutions for mentoring and collaboration.

For Development Partners and Donors: Fund SEM capacity-building initiatives in African universities; support longitudinal data collection; finance research networks that facilitate SEM applications to African development questions; commission SEM-based research on priority policy questions.

For African Researchers: Adopt SEM for appropriate research questions; publish SEM applications in African and international journals; mentor younger researchers in SEM methodology; engage with policymakers to ensure research addresses actual policy questions.

For African Policymakers: Commission research using SEM to understand policy mechanisms; create research-policy forums where academics present SEM findings; invest in government capacity to understand and utilise SEM-based analysis in policy design.

### Final Thoughts

African development research stands at a Critical juncture. The field has generated substantial empirical work on crucial policy questions, yet much of this work employs methodologies that may not adequately capture the complexity of development processes. Structural Equation Modeling offers a methodological pathway that is both theoretically sophisticated (grounded in Critical Realism) and practically applicable to African contexts. The adoption of SEM by African researchers and institutions would not only improve research quality but would also signal to the international academic community that African research represents a frontier of methodological innovation. The time for this transition is now.

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