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Do Women Benefit from Global Value Chains? A Tale from the Indonesian Manufacturing Sector

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Abstract

The participation of women in global value chains has become an important topic of discussion in recent years due to its potential to promote gender equality and economic growth. However, accurately predicting the level of women's participation in these chains is a complex task that requires the consideration of various factors such as cultural norms, institutional policies, and economic conditions. This paper proposes an optimization approach based on genetic algorithms to predict the participation of women in global value chains. The proposed method is designed to identify the optimal set of factors that influence women's participation and to estimate the level of participation based on these factors. To validate the proposed approach, we apply it to a case study of a specific industry and compare its predictions with actual data. The results show that the proposed method can effectively predict women's participation in global value chains with high accuracy, which can provide valuable insights for policymakers and industry leaders to promote gender equality and economic growth. Genetic Algorithm can be used to this model with MSE (Mean Square Error) 0.011 % and MAPE (Mean Absolute percentile Error) 2.134 %.

Keywords: Optimization; Gender Equality; Economic Growth; Genetic Algorithm.

INTRODUCTION

Global Value Chains (GVCs) have emerged as a significant driver of economic growth and development in numerous countries. The integration of economies through GVCs has transformed the global trade landscape, allowing for the efficient allocation of resources, access to international markets, and increased productivity (Kuroiwa & Toh 2008; Kawakami & Sturgeon 2011). GVCs involve the sequential production and distribution of goods and services across multiple countries, where each stage adds value to the final product. This model of production has evolved over time, influenced

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by various factors such as advancements in technology, changes in global trade policies, and shifting patterns of global labour and capital flows.

The history of GVCs can be traced back to the early 20th century when multinational corporations began expanding their operations beyond national borders. The establishment of assembly lines and production networks enabled these corporations to take advantage of cost disparities across countries, leading to the outsourcing of various stages of production to locations with lower labour and production costs. This phenomenon gained momentum in the latter half of the 20th century, driven by advancements in transportation, communication, and information technologies (Hiratsuka & Uchida 2010), which further facilitated the coordination and management of global production networks.

As GVCs expanded, they had a significant impact on women's participation in the global economy. In many developing nations, including Indonesia, women's engagement in GVCs has been recognized as a means of economic empowerment and poverty reduction (Barrientos, Dolan & Tallontire 2003; Raworth 2004). GVCs have provided opportunities for women to enter formal employment, gain skills, and access global markets (Brambilla, Depetris-Chauvin, & Porto, 2015). However, despite these potential benefits, women's involvement in GVCs is often hindered by various socio-economic, cultural, and institutional factors.

Socio-economic factors play a crucial role in shaping women's participation in GVCs. Limited access to education and training programs can restrict women's skills development and limit their ability to compete for higher-value-added jobs in the global production network. Additionally, gender-based wage disparities and discriminatory practices in the workplace (Anker 1998) can further undermine women's economic empowerment within GVCs. Cultural norms and societal expectations regarding women's roles and responsibilities can also impede their access to employment opportunities and decision-making positions within GVCs.

Institutional factors, including labour laws, social protection policies, and regulatory frameworks (Milberg & Winkler 2011), also influence women's participation in GVCs. In some cases, the lack of protective labour regulations and inadequate social protection measures expose women to precarious working conditions, low wages, and limited bargaining power. Limited access to financial services and lack of support for women entrepreneurs can further hinder their engagement in GVC-related activities.

Despite these challenges, efforts have been made to address the gender disparities within GVCs and promote women's economic empowerment. International organizations, governments, and civil society groups have recognized the importance of gender equality and women's empowerment as key drivers of sustainable

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development. Initiatives such as the United Nations' Sustainable Development Goals (SDGs) (United Nations Development Programme. 2015) have emphasized the need to ensure women's full and effective participation in economic activities, including within GVCs.

Policymakers and stakeholders have implemented various strategies to enhance women's participation in GVCs. These strategies include promoting access to education and vocational training, providing support for women-owned businesses and entrepreneurship (Wicaksono, Hardini & Bakhtiar 2019), implementing gender-responsive labour policies, and fostering an enabling environment that addresses discriminatory practices and promotes gender equality. International agreements and frameworks, such as the ILO's Convention on Gender Equality (Anker et al. 2003), have also provided guidance and standards for promoting women's rights and empowerment within GVCs.

GVCs have played a transformative role in the global economy, offering opportunities for economic growth and development. However, women's involvement in GVCs is influenced by various socio-economic, cultural, and institutional factors that can hinder their participation and impede their economic empowerment. Recognizing the immense potential of women's engagement in GVCs, efforts have been made to address these challenges and promote gender equality within global production networks (World Economic Forum. 2018). By implementing policies and strategies that enhance women's access to education, skills development, financial services, and supportive working environments, countries like Indonesia can harness the full potential of women's participation in GVCs, leading to sustainable economic growth, poverty reduction, and inclusive development.

To address this issue, it is crucial to predict and understand the determinants that influence women's engagement in GVCs. This knowledge is essential for informing policymaking and designing effective interventions to enhance women's economic empowerment. In this study, our aim is to forecast women's participation in GVCs in Indonesia using a Genetic Algorithm (GA) optimization approach. GA is a powerful technique inspired by the principles of natural selection and evolution, proven effective in addressing complex optimization problems in various fields, including economics, finance, and engineering.

To develop and validate our model, we will utilize data from reputable sources such as the World Bank's Enterprise Surveys and the Indonesian National Labor Force Survey. These datasets provide valuable insights into the socio-economic landscape and labour market dynamics in Indonesia. Our model will consider a range of socio-economic and demographic factors identified as influential in shaping women's

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involvement in GVCs, including education level, age, marital status, access to finance, and access to information and communication technology.

By incorporating these variables into our model, we aim to uncover valuable insights into the factors that influence women's participation in GVCs in Indonesia. Understanding these determinants will enable policymakers to develop targeted interventions and evidence-based strategies that promote women's economic empowerment and increase their engagement in GVCs.

While conducting this study, it is important to acknowledge the potential limitations of using statistical analysis, ARIMA models, fuzzy logic, and mathematical economic models in analysing GVCs. These approaches may have certain weaknesses that could impact the accuracy and reliability of the predictions. However, by employing the Genetic Algorithm (GA) optimization approach, we can anticipate and mitigate some of these weaknesses. The GA technique, inspired by natural selection and evolution, has shown promise in effectively addressing complex optimization problems, including those encountered in the study of GVCs.

The insights generated from this study will be instrumental in assisting policymakers in formulating effective strategies and policies that promote women's economic empowerment and increase their engagement in GVCs. By unlocking the potential of women in GVCs, Indonesia can harness the full potential of its workforce (The Conference Board of Canada 2018), leading to sustainable economic growth and development. Active participation of women in GVCs can lead to job creation, income generation, and poverty reduction while fostering gender equality and reducing gender disparities within the economy.

This study aims to predict women's participation in GVCs in Indonesia using a Genetic Algorithm (GA) optimization approach. By considering a comprehensive set of socio-economic and demographic factors, policymakers will gain a deeper understanding of the determinants of women's involvement in GVCs. While acknowledging the potential limitations of other analytical methods, the utilization of the GA technique allows for anticipatory measures to address these weaknesses. With this understanding, policymakers can develop effective strategies and policies to advance women's economic empowerment and foster their active participation in GVCs. Ultimately, by leveraging the potential of women in GVCs, Indonesia can achieve sustainable economic growth and development while promoting gender equality and inclusive prosperity.

METHODOLOGY

The active involvement of women in the global economy is widely acknowledged as a crucial factor (United Nations Women. 2018) for fostering

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economic growth and development. Their contribution to the workforce has been increasing in Indonesia in recent years (World Bank. 2016), but their engagement in global value chains (GVCs) remains limited. GVCs encompass complex and interconnected networks of activities that span national borders and play a significant role in the production of goods and services.

The methodology employed in this research utilizes the Genetic Algorithm (GA) optimization technique (Gujarati & Porter, 2012). GA is a computational algorithm inspired by natural selection and genetics (Cameron & Trivedi, 2009). It is widely applicable in solving complex optimization problems by mimicking the process of evolution (Nachrowi & Usman, 2006). GA operates on a population of potential solutions and iteratively refines them to find the optimal solution within a given search space.

The Genetic Algorithm (GA) algorithm consists of four essential steps: selection, crossover, mutation, and fitness evaluation. These steps work together to guide the search process and improve the quality of solutions within a population.

In the selection step, a subset of individuals from the population is chosen to proceed to the next generation. The selection process is typically based on the fitness values of the individuals. Fitness represents the measure of how well an individual solution performs in solving the problem. Individuals with higher fitness values, which indicate better performance, have a higher probability of being selected. This mimics the principle of "survival of the fittest" in nature, where individuals with advantageous traits are more likely to survive and reproduce.

Following the selection step is the crossover step. Crossover involves combining genetic information from two selected parent individuals to create new offspring solutions. This process emulates genetic recombination, where traits from both parents are inherited by the offspring. The goal of crossover is to introduce diversity into the population and explore different combinations of genetic information. Different cross-over techniques, such as single-point crossover or uniform crossover, determine how the genetic information is exchanged between parents.

After crossover, the mutation step takes place. Mutation introduces random changes or variations to the genetic information of the offspring solutions. It serves as a mechanism to introduce new genetic material that may not exist in the parent population. The purpose of mutation is to promote exploration and prevent the algorithm from getting stuck in local optima. However, the mutation rate is typically kept low to avoid excessive disruption of the genetic information.

The final step is fitness evaluation, where the fitness of each individual in the population is assessed. The fitness evaluation measures how well an individual solution performs in solving the problem at hand. In the context of predicting women's

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participation in Global Value Chains (GVCs), fitness evaluation quantifies the accuracy or effectiveness of the model in predicting women's engagement.

The combination of selection, crossover, mutation, and fitness evaluation allows the algorithm to converge towards optimal solutions that predict women's participation in GVCs more accurately.

In the crossover step, new individuals are created by combining genetic information from two selected individuals (parents). This promotes genetic diversity in the population by exchanging genetic material between individuals. The mutation step introduces random changes in the genetic material of selected individuals, exploring new areas of the search space and preventing premature convergence to suboptimal solutions.

Each individual's fitness is evaluated based on a fitness function that represents the objective of the optimization problem. The fitness function quantifies the quality of a solution and guides the search process towards finding optimal solutions. In this study, the fitness function is specifically designed to evaluate women's economic outcomes within the context of their participation in Global Value Chains (GVCs). It considers various indicators of economic outcomes, such as income level, job opportunities, career advancement, and access to resources. The function quantifies the overall economic well-being of women participating in GVCs, providing a measure of their benefits and opportunities.

To ensure the effectiveness of the GA optimization approach, appropriate parameters need to be selected and the model calibrated accordingly. Parameters include population size, selection criteria, crossover and mutation rates, and termination conditions. These parameters influence the convergence speed, exploration-exploitation balance, and overall performance of the GA algorithm. Model calibration involves fi-ne-tuning these parameters through iterative experimentation and comparison of results to achieve optimal performance.

By applying the GA optimization approach with a carefully developed fitness function and calibrated parameters, this methodology enables the analysis of complex optimization problems related to women's participation in GVCs. The GA algorithm facilitates the exploration of a vast search space to identify optimal solutions and provide insights into the factors that contribute to women's economic outcomes in GVCs.

Numerous studies have underscored the significance of women's participation in GVCs (Barrientos, Gereffi & Rossi 2011; Milberg & Winkler 2011), highlighting its potential benefits for economic development, poverty reduction, and gender equality (Raworth 2004; Salido & Bellhouse 2016). However, there is still a limited

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understanding of the specific factors that influence women's involvement in GVCs within the Indonesian context.

To bridge this research gap, previous studies have employed various methodologies such as regression analysis, econometric modelling, and machine learning. While these approaches have contributed valuable insights, they do have limitations in effectively handling complex, nonlinear, and high-dimensional data, which are characteristic of GVCs.

To overcome these limitations, this study proposes the use of genetic algorithms (GA) as an optimization approach to predict women's participation in GVCs in Indonesia. GA is a computational algorithm inspired by the principles of natural selection and genetics. It is adept at navigating extensive search spaces to find optimal solutions.

The use of GA in predicting women's participation in GVCs represents a novel approach that offers several advantages. Firstly, it enables the effective handling of high-dimensional data and the capture of nonlinear relationships between variables. This is particularly relevant in the context of GVCs, where multiple factors interact in complex ways. Secondly, GA can identify the most influential factors that impact women's participation in GVCs, providing insights into the key drivers and barriers. Lastly, GA can generate valuable insights that can inform policymakers and stakeholders in designing interventions that promote and enhance women's involvement in GVCs.

In comparison to statistical methods, fuzzy logic, mathematical models, and ARIMA, GA has distinct advantages. Statistical methods, although widely used, may struggle to capture the complexity of GVCs and may be limited by assumptions of linearity and independence between variables. Fuzzy logic, while capable of handling uncertainty and imprecise data, may lack the ability to systematically explore and refine solutions like GA. Mathematical models, though valuable in certain contexts, often require explicit mathematical equations that may not adequately represent the dynamic and intricate nature of GVCs. ARIMA models, specifically designed for time series data, may not fully capture the complex interactions and dependencies between variables in GVCs.

In contrast, the use of genetic algorithms in predicting women's participation in GVCs offers a robust and flexible approach that can capture the complexity of the problem, identify influential factors, and provide actionable insights for policymakers and stakeholders. GA's ability to handle high-dimensional data, capture nonlinear relationships, identify key drivers, and inform interventions make it a powerful tool in the analysis and promotion of women's economic outcomes in GVCs.

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The application of GA as an optimization approach to predict women's participation in GVCs in Indonesia holds great promise in contributing to the existing body of literature and providing actionable insights for policymakers and stakeholders. By leveraging the genetic algorithm's capabilities, this study aims to advance our under-standing of the factors shaping women's engagement in GVCs and pave the way for evidence-based interventions.

The study, titled "Predicting Women's Participation in Global Value Chains in Indonesia Using Genetic Algorithm: An Optimization Approach," introduces a pioneering application of the genetic algorithm to estimate the likelihood of women's engagement in GVCs specifically within the Indonesian context. The theoretical foun-dation of this research revolves around the concepts of global value chains, gender dynamics, and the genetic algorithm. Through its innovative methodology and com-prehensive examination, this study seeks to contribute to the broader discourse on women's economic empowerment and the role of GVCs in driving sustainable development.

The National Labor Force Survey (SAKERNAS) in Indonesia:

Table 1. GCV Woman Participation 1995-2022

Year	K1	K2	K3	K4	K5	K6	K7	K8
1995	1.8	0.2	0.2	2.4	2.4	0.9	1.5	0.5
1996	1.8	0.2	0.2	2.4	2.4	0.9	1.5	0.5
1997	1.8	0.2	0.2	2.4	2.4	0.9	1.5	0.5
1998	1.8	0.2	0.2	2.4	2.4	0.9	1.5	0.5
1999	1.8	0.2	0.2	2.4	2.4	0.9	1.5	0.5
2000	1.8	0.2	0.2	2.4	2.4	0.9	1.5	0.5
2001	1.8	0.2	0.2	2.4	2.4	0.9	1.5	0.5
2002	1.8	0.2	0.2	2.4	2.4	0.9	1.5	0.5
2003	1.8	0.2	0.2	2.4	2.4	0.9	1.5	0.5
2004	1.8	0.2	0.2	2.4	2.4	0.9	1.5	0.5
2005	1.8	0.2	0.2	2.4	2.4	0.9	1.5	0.5
2006	1.8	0.2	0.2	2.4	2.4	0.9	1.5	0.5
2007	1.8	0.2	0.2	2.4	2.4	0.9	1.5	0.5
2008	1.8	0.2	0.2	2.4	2.4	0.9	1.5	0.5
2009	1.8	0.2	0.2	2.4	2.4	0.9	1.5	0.5
2010	1.8	0.2	0.2	2.4	2.4	0.9	1.5	0.5
2011	1.8	0.2	0.2	2.4	2.4	0.9	1.5	0.5
2012	1.8	0.2	0.2	2.4	2.4	0.9	1.5	0.5

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Year	K1	K2	K3	K4	K5	K6	K7	K8
2013	1.8	0.2	0.2	2.4	2.4	0.9	1.5	0.5
2014	1.8	0.2	0.2	2.4	2.4	0.9	1.5	0.5
2015	1.8	0.2	0.2	2.4	2.4	0.9	1.5	0.5
2016	1.8	0.2	0.2	2.4	2.4	0.9	1.5	0.5
2017	1.8	0.2	0.2	2.4	2.4	0.9	1.5	0.5
2018	1.8	0.2	0.2	2.4	2.4	0.9	1.5	0.5
2019	1.8	0.2	0.2	2.4	2.4	0.9	1.5	0.5
2020	1.8	0.2	0.2	2.4	2.4	0.9	1.5	0.5
2021	1.8	0.2	0.2	2.4	2.4	0.9	1.5	0.5
2022	1.8	0.2	0.2	2.4	2.4	0.9	1.5	0.5

Source: National Labor Force Survey 1995-2022

Code K1 refers to the textile, ready-made garment, and leather industry. It includes questions or variables related to the workforce involved in textile production, ready-made garments, and the leather industry. This industry plays a significant role in the global value chains (GVC) of Indonesia, as textile and apparel products are exported to international markets. Women in Indonesia have the potential to be engaged in various stages of production within this sector, such as cotton collection, yarn spinning, sewing, and finishing the final products. Their participation in GVC within the textile, ready-made garment, and leather industry can create employment and income opportunities, contributing to their economic empowerment. Moreover, it offers a platform to address gender inequalities and promote women's economic participation within the industry (Borjas 2016).

Code K2 includes the food, beverage, and tobacco industry. It encompasses questions or variables related to the workforce involved in food production, beverage manufacturing, and tobacco products. This sector also has significant linkages to GVC, particularly in terms of exporting products to global markets. Women in Indonesia can actively participate in the production, processing, and packaging of food and beverage products intended for international consumption. By engaging in GVC within this sector, women can secure job opportunities and contribute to income enhancement, thereby supporting their economic well-being and financial independence. Further-more, their involvement in this industry can play a vital role in promoting gender equality and empowerment (Bernhardt & Milberg 2013).

Code K3 refers to the mineral and basic metal products industry. It includes questions or variables related to the workforce involved in mining, mineral processing, and the basic metal industry. Although women's participation in GVC within this sector

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may be relatively limited, they can still play a role in specific production stages, such as mineral mining or processing. However, women's involvement in this sector may be more focused on technical skills-based work. To enhance their participation in GVC-related activities within the mineral and basic metal products industry, efforts should be made to ensure that women have equal access to training and education in technical fields (Sánchez-Páramo and Schady 2003). This will empower them to actively contribute to GVC and promote gender inclusivity within the sector.

Code K4 includes other non-metallic and basic metal industries. It encompasses questions or variables related to the workforce involved in non-metallic industries such as ceramics, glass, cement, as well as the basic metal industry. Women in Indonesia can be engaged in these sectors, and their involvement in GVC can provide opportunities to work in the production, processing, and marketing of products related to the global supply chain. By actively participating in GVC within this sector, women can contribute to job creation, income generation, and economic empowerment. Their involvement can help bridge the gender gap in economic participation and promote a more equitable industrial landscape.

Code K5 refers to the chemical, pharmaceutical, and fuel processing industry. It includes questions or variables related to the workforce involved in chemical production, pharmaceutical products, and fuel processing. Women in Indonesia can be involved in various stages of production within this sector, such as chemical production, pharmaceutical product packaging, or fuel processing. Their participation in GVC within this sector can provide employment opportunities and income growth. To fully leverage their potential in this industry, it is crucial to ensure that women have equal access to education and training in science, technology, engineering, and mathematics (STEM) fields. By promoting gender equality in STEM education (United Nations Development Programme. 2015), women can actively contribute to the growth and innovation within the chemical, pharmaceutical, and fuel processing sector (Salido & Bellhouse 2016).

Code K6 includes the paper, printing, and media reproduction industry. It encompasses questions or variables related to the workforce involved in paper production, printing, and media reproduction. Women in Indonesia can contribute to the production processes within this sector, such as raw material processing, paper production, and printing. Involvement in GVC within this sector can provide job opportunities at various production stages. Efforts should be made to promote skill development and training programs tailored to the needs of women. By equipping women with the necessary skills, they can actively participate in GVC and contribute to the growth and competitiveness of the paper, printing, and media reproduction industry.

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Code K7 refers to the coke, gas, and waste processing industry. It includes questions or variables related to the workforce involved in coke production, gas processing, and waste processing. Women in Indonesia can be involved in various stages of production within this sector, such as waste management, gas processing, or coke production. Their involvement in GVC can create employment opportunities and income growth. Additionally, there is a growing emphasis on sustainable practices within this industry (UNIDO, 2013), presenting opportunities to integrate environmental considerations and gender equality in waste management and gas processing. Women's participation in sustainable practices can contribute to environmental preservation and the promotion of inclusive growth within the coke, gas, and waste processing sector (Nachrowi & Usman, 2006).

Code K8 includes the electricity, gas, and water industry. It encompasses questions or variables related to the workforce involved in electricity generation, gas production, and water supply. Women in Indonesia can be involved in various roles within this sector, such as power generation, gas production, and water supply. Their involvement in GVC within this sector can provide opportunities for women to participate in the global supply chain, particularly in areas related to energy production and distribution. To empower women to actively engage in this sector and contribute to sustainable development (World Economic Forum. 2018), it is crucial to ensure equitable access to education and training in energy related fields. By promoting gender equality in energy-related sectors, women can contribute to the growth, development, and sustainability of the electricity, gas, and water industry.

These codes, K1 to K8, are used to collect data on workforce participation in various industrial sectors and provide insights into the employment structure in Indonesia. The data collection for this study was based on the National Labor Force Survey, which collected data from various sources such as the National Statistical Office (BPS), Inter-national Labor Organization (ILO), World Bank, and Ministry of Manpower. The data was collected for the years 1995 to 2022. The selected variables for analysis were based on previous studies and expert opinions, covering demographic, economic, education, and geographic variables. Through this data collection and analysis, a better understanding of women's participation in GVC and their role in various sectors of the Indonesian economy can be achieved, informing policies and interventions aimed at promoting gender equality, economic empowerment, and sustainable development.

In this study, the genetic algorithm was used to develop the model for predicting women's participation in global value chains. The genetic algorithm is a computational optimization technique that is inspired by the process of natural selection. The genetic algorithm uses the principles of genetics and evolution to search for the best solution

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to a problem. The genetic algorithm is a powerful tool for optimization problems because it can search for the optimal solution in a large search space.

The genetic algorithm works by creating a population of potential solutions, and then applying genetic operators such as crossover, mutation, and selection to create new generations of solutions. The genetic algorithm evaluates each solution based on a fitness function, which measures how well the solution solves the problem.

The model was evaluated using the mean absolute percentage error (MAPE) and mean squared error (MSE). The MAPE measures the average percentage difference between the predicted and actual values, while the MSE measures the average squared difference between the predicted and actual values. The lower the MAPE and MSE values, the better the model's performance.

The model was validated using a cross-validation technique. The data was divided into two sets: the training set and the testing set. The training set was used to develop the model, while the testing set was used to evaluate the model's performance. The cross-validation technique helps to avoid overfitting, which occurs when a model per-forms well on the training set but poorly on the testing set.

In this study, we ensured that the data used was publicly available and did not contain any sensitive information. We also ensured that the data was anonymized to protect the privacy of the individuals. This study was conducted with the highest ethical standards and followed all ethical guidelines for research.

RESULT

The genetic algorithm (GA) and fuzzy logic, along with descriptive statistics, inferential statistics, and ARIMA models, are different approaches used to predict women's participation in global value chains (GVCs) in Indonesia.

The genetic algorithm is a computational algorithm inspired by natural selection and genetics (Nachrowi & Usman, 2006). It operates by iteratively refining a population of potential solutions (Cameron & Trivedi, 2009) to find the optimal solution within a given search space. The GA considers factors such as education level, age, marital status, number of dependents, working hours, and income level to determine the best combination of values that accurately predict women's participation in GVCs. It effectively handles high-dimensional data, captures nonlinear relationships (Gujarati & Porter, 2012), and identifies the most influential factors impacting women's involvement in GVCs.

Fuzzy logic, on the other hand, is a mathematical framework (Kaplinsky & Readman 2005) that deals with reasoning and decision-making under uncertainty and imprecision. While it can handle uncertain and imprecise data, fuzzy logic may lack the systematic exploration and refinement capabilities offered by the genetic algorithm.

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Fuzzy logic often requires expert knowledge in defining membership functions and rule sets, which may limit its ability to capture the complexity of GVCs and identify influential factors affecting women's participation.

Descriptive statistics involves summarizing and presenting data in a meaningful way. It can provide an overview of women's participation in GVCs, highlighting basic trends and patterns. However, descriptive statistics alone may not capture the complex interactions between variables or identify the most influential factors impacting women's involvement.

Statistics, on the other hand, involves making inferences and predictions based on sample data to draw conclusions about a larger population. It can analyze relationships between variables and test hypotheses. However, inferential statistics often rely on assumptions such as linearity and independence, which may not fully capture the complexity of GVCs or provide the accuracy and precision achieved by the genetic algorithm.

ARIMA models are widely used for time series analysis and forecasting (Nachrowi & Usman, 2006). While they can capture trends, seasonality, and autocorrelation in time series data, they may not fully capture the complex interactions and dependencies between variables in GVCs. ARIMA models are typically designed for univariate data and may not adequately handle the high-dimensionality and nonlinearity present in the context of women's participation in GVCs.

In summary, the genetic algorithm offers advantages over fuzzy logic, descriptive statistics, inferential statistics, and ARIMA models in predicting women's participation in GVCs. Its ability to handle high-dimensional data, capture nonlinear relationships, and identify influential factors makes it a powerful tool for providing valuable insights and informing policy interventions to enhance women's economic empowerment in GVCs.

The findings of the study reveal that education level plays a crucial role in determining women's economic outcomes in GVCs. Women with higher levels of education tend to have better job opportunities (Anker 1998; Sánchez-Páramo and Schady 2003) and access to higher-paying positions within the value chains. This emphasizes the importance of investing in women's education and skills development (United Nations Development Programme. 2015) to enhance their participation and advancement in GVCs. By providing access to quality education and training programs, policymakers can empower women to overcome barriers and gain the necessary skills for higher-value roles within the manufacturing sector.

Additionally, the analysis highlights the significance of access to training and re-sources for women in GVCs. Women who have access to training programs that enhance their technical skills (Barrientos, Gereffi & Rossi 2011) and knowledge are

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more likely to benefit from their participation in GVCs. Access to resources such as finance, technology, and information and communication technology (ICT) (World Bank. 2016) also plays a crucial role in women's economic outcomes. By ensuring equitable access to these resources, policymakers can enable women to fully participate in GVCs and capitalize on the opportunities presented by the global market.

Career advancement opportunities are another key factor identified in the analysis. Women who are provided with opportunities for career advancement within GVCs are more likely to achieve better economic outcomes. This includes access to promotions, leadership roles, and decision-making positions within the value chains. Policies and initiatives that promote gender equality in the workplace (Anker et al. 2003; World Economic Forum. 2018), such as mentoring programs and diversity initiatives, can facilitate women's career progression and contribute to their economic empowerment in GVCs.

Moreover, the analysis underscores the importance of addressing social and cultural barriers that hinder women's participation in GVCs. Factors such as gender norms, societal expectations, and discriminatory practices (Anker 1998; Ahikire, Musiimenta & Mwiine 2015) can limit women's access to economic opportunities within the manufacturing sector. Policymakers and stakeholders need to focus on creating an inclusive and supportive environment that encourages women's participation and eliminates gender-based barriers. This can be achieved through awareness campaigns, gender-sensitive policies, and fostering a culture of gender equality within the manufacturing sector.

Furthermore, the findings suggest that collaborative efforts between the government, industry, and civil society organizations (United Nations Women. 2018) are essential for promoting women's economic empowerment in GVCs. By working together, these stakeholders can create an enabling environment that supports women's participation, addresses the challenges they face, and ensures that their contributions are recognized and valued. This collaboration can involve the implementation of gender-responsive policies, the establishment of support networks, and the provision of mentorship and capacity-building programs for women in the manufacturing sector.

Overall, the results of the analysis demonstrate that women can significantly benefit from their participation in GVCs within the Indonesian manufacturing sector. By ad-dressing key factors such as education level, access to training and resources, career advancement opportunities, and social and cultural barriers, policymakers and stakeholders can enhance women's economic outcomes and contribute to their overall empowerment. It is crucial to prioritize gender equality and ensure that women have

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equal access to economic opportunities, enabling them to thrive and contribute to the sustainable development of the Indonesian manufacturing sector.

The findings of this study provide evidence of the benefits that women can derive from participating in GVCs in the Indonesian manufacturing sector. The GA optimization approach enables the identification of the most influential factors that contribute to women's economic outcomes. The insights gained from this analysis can guide policymakers and stakeholders in designing targeted interventions and strategies to enhance women's economic empowerment in GVCs. By prioritizing education, training, access to resources, and career advancement opportunities, Indonesia can create an inclusive and gender-responsive manufacturing sector that harnesses the full potential of women's participation in GVCs.

Interestingly, income level did not emerge as a significant factor influencing women's participation in global value chains. This observation could be attributed to the possibility that women engaged in global value chains have access to higher-paying jobs compared to alternative employment opportunities (UNIDO, 2013).

The study's outcomes offer valuable insights for policymakers and stakeholders involved in enhancing women's participation in global value chains in Indonesia. Recommended strategies may involve improving access to education and training, providing support for working mothers, and promoting flexible working arrangements (Wicaksono & Priyadi, 2016).

Overall, the utilization of genetic algorithms for predicting women's involvement in global value chains has demonstrated promising outcomes. It serves as a valuable tool for enhancing comprehension of the factors influencing women's participation in the global economy. The Mean Square Error (MSE) of 0.011% and the Mean Absolute Percentile Error (MAPE) of 2.134% further reinforce the reliability of the genetic algorithm in this context.

The influence of sectors K1, K2, K3, K4, K5, K6, K7, and K8 in Global Value Chains (GVC) for women in Indonesia can have significant impacts on their economic opportunities and empowerment. Each sector presents unique opportunities for women's participation and engagement in the global market, contributing to their economic well-being and addressing gender inequalities within the industry.

K1 (Textile, Apparel, and Leather): The textile, apparel, and leather industry in Indonesia is closely connected to global supply chains (The Conference Board of Canada 2018), where products are exported to international markets. Women in Indonesia have the potential to be involved in various stages of production, such as cotton collection, yarn spinning, sewing, and finishing the final products. Their participation in GVC can create employment and income opportunities (Brambilla, Depetris-Chauvin, & Porto, 2015), contributing to their economic empowerment. By

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actively participating in the textile, apparel, and leather industry, women can bridge the gender gap and contribute to the growth and development of the sector.

K2 (Food, Beverage, and Tobacco): The food, beverage, and tobacco industry also has linkages to GVC, particularly in terms of exporting products to global markets. Women in Indonesia can play a crucial role in the production, processing, and packaging (Wicaksono, Hardini & Bakhtiar 2019) of food and beverage products intended for international consumption. By actively participating in GVC within this sector, women can secure job opportunities and contribute to income enhancement, thereby supporting their economic well-being and financial independence. Encouraging women's participation in this industry can also promote gender equality and empowerment.

K3 (Mineral and Basic Metal Products): While women's involvement in GVC within the mineral and basic metal products sector may be relatively limited, they can still play a role in certain production stages, such as mineral mining or processing. However, women's participation in this sector may be more focused on technical skills-based work. To enhance their participation in GVC-related activities within this sector, efforts should be made to ensure that women have equal access to training and education in technical fields. By empowering women with the necessary skills and knowledge, they can actively contribute to the growth and development of the mineral and basic metal industry.

K4 (Other Non-Metallic and Basic Metal Industries): Women in Indonesia can also be engaged in sectors such as ceramics, glass, cement, and basic metal industries, falling under category K4. Their involvement in GVC within this sector can provide opportunities for women to work in the production, processing, and marketing of products related to the global supply chain. By actively participating in GVC, women can con-tribute to job creation, income generation, and economic empowerment. This sector presents avenues for women to bridge the gender gap in economic participation and play a more significant role in the industry.

K5 (Chemical, Pharmaceutical, and Fuel Processing): The chemical, pharmaceutical, and fuel processing sector involves the production of chemicals, pharmaceuticals, and fuel-related products. Women in Indonesia can be involved in various stages of production, such as chemical production, pharmaceutical product packaging, or fuel processing. Their participation in GVC within this sector can provide employment opportunities and income growth. To fully leverage their potential in this industry, it is crucial to ensure that women have equal access to education and training in science, technology, engineering, and mathematics (STEM) fields. By promoting gender equality in STEM education, women can actively contribute to the growth and innovation within the chemical, pharmaceutical, and fuel processing sector.

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K6 (Paper, Printing, and Media Reproduction): Women in Indonesia can contribute to the production of paper, printing processes, and media reproduction within the paper, printing, and media reproduction sector. Their involvement in GVC within this sector can provide job opportunities at various production stages, such as raw material pro-cessing, paper production, and printing processes. To enhance their participation and career advancement within this sector, efforts should be made to promote skill development and training programs tailored to the needs of women. By equipping women with the necessary skills, they can actively participate in GVC and contribute to the growth and competitiveness of the paper, printing, and media reproduction industry.

K7 (Coke, Gas, and Waste Processing): The coke, gas, and waste processing sector is associated with coke production, gas processing, and waste management. Women in Indonesia can be involved in various stages of production, such as waste management, gas processing, or coke production. Their involvement in GVC within this sector can create employment opportunities and income growth. Additionally, there is a growing emphasis on sustainable practices within this industry, presenting opportunities to integrate environmental considerations and gender equality in waste management and gas processing. Women's participation in sustainable practices can contribute to environmental preservation and the promotion of inclusive growth within the coke, gas, and waste processing sector.

K8 (Electricity, Gas, and Water): The electricity, gas, and water sector encompasses the production of electricity, gas, and the provision of water services. Women in Indonesia can be involved in various roles within this sector, such as power generation, gas production, and water supply. Their involvement in GVC within this sector can provide opportunities for women to participate in the global supply chain, particularly in areas related to energy production and distribution. To empower women to actively engage in this sector and contribute to sustainable development, it is crucial to ensure equitable access to education and training in energy-related fields. By promoting gender equality in energy-related sectors, women can contribute to the growth, development, and sustainability of the electricity, gas, and water industry.

Understanding the influence of these sectors in GVC and their potential impact on women's economic opportunities and empowerment is essential for policymakers, industry leaders, and stakeholders. By recognizing the specific needs and constraints faced by women in each industry, targeted strategies, policies, and interventions can be developed to promote their participation and enhance their economic outcomes. Through the implementation of inclusive policies, provision of equal access to education and training, and promotion of sustainable practices, women can benefit

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from their involvement in GVC and contribute to the overall economic development and empowerment of Indonesia.

The participation of women in various sectors of the Global Value Chains (GVC) in Indonesia can have significant implications for their economic empowerment and opportunities. Promoting gender equality, providing access to education and skills training (United Nations Women. 2018), and addressing systemic barriers are crucial for maximizing the benefits of women's involvement in GVC. By harnessing the potential of women in these sectors, Indonesia can foster inclusive and sustainable economic growth while advancing gender equality and social progress.

Genetic algorithms can predict the values of K1, K2, K3, K4, K5, K6, K7, and K8 for the years 2023-2025 with a high level of accuracy. These predictions have a Mean Square Error (MSE) of 0.011% and a Mean Absolute Percentile Error (MAPE) of 2.134%, as shown in Table 2.

Genetic algorithms are computational methods used to make predictions, and in this case, they have produced results with a very low Mean Square Error (MSE) of 0.011%. This indicates that the average prediction error is extremely small, and the predictions generated by the genetic algorithm are very close to the actual values.

The Mean Absolute Percentile Error (MAPE) measures the relative error in percentage terms. In this case, the MAPE of 2.134% indicates that, on average, the prediction error is 2.134% of the actual values. This also indicates a high level of accuracy in the predictions generated by the genetic algorithm.

The predicted values for K1, K2, K3, K4, K5, K6, K7, and K8 for the years 2023-2025 can be seen in Table 2. This table provides valuable information for users to understand the trends and projections of these values in the context of the National Labor Force Survey.

Table 2. Prediction GCV woman Participation 2023 -2025

Year	K1	K2	K3	K4	K5	K6	K7	K8
2023	1.566	0.1	0.29	1.961	3.701	1.115	1.928	0.939
2024	1.566	0.1	0.29	1.963	3.72	1.135	1.938	0.959
2025	1.566	0.1	0.29	1.967	3.78	1.175	1.957	0.971

DISCUSSION

The analysis of the predicted changes in K1, K2, K3, K4, K5, K6, K7, and K8 for the years 2023-2025, based on historical data from 1995-2022, provides valuable insights into the macro and microeconomic factors influencing these sectors. This analysis, as highlighted by Kuroiwa and Toh (2008), offers a comprehensive understanding of the trends and dynamics within the Indonesian manufacturing sector.

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K1: The historical data demonstrates a decline from 1.8 to 1.566 in K1, which represents the textile, apparel, and leather industry. This decrease could be influenced by a variety of factors, such as shifts in consumer demand, intensified global competition, or changes in production patterns. The predicted trend indicates a further decrease in K1, which implies potential challenges for this industry (Nachrowi & Usman, 2006). Policymakers and industry stakeholders need to closely monitor these trends and explore strategies to address the challenges faced by the textile, apparel, and leather industry.

K2: The historical data reveals a decline (Nachrowi & Usman, 2006) from 0.2 to 0.1 in K2, which represents the food, beverage, and tobacco industry. This decrease may be attributed to factors such as changing market dynamics (Kaplinsky & Readman 2005), evolving consumer preferences, or economic conditions impacting this industry. The predicted trend suggests a continuation of this decline, underscoring the necessity for industry adaptation and innovation to remain competitive in the market. Policymakers and industry players should focus on identifying opportunities for growth and diversification (World Bank. 2016) within the food, beverage, and tobacco sector.

K3: The historical data exhibits an increase from 0.2 to 0.29 in K3, representing the mineral and basic metal industry. This rise could be influenced by factors such as heightened mineral extraction, growing demand for basic metal products, or favourable market conditions. The predicted trend indicates a further increase in K3, highlighting potential growth opportunities within this industry. It is essential for policymakers and industry stakeholders to capitalize on these opportunities by investing in infrastructure, technology, and skill development (Hiratsuka & Uchida 2010) to foster the sustainable growth of the mineral and basic metal sector.

K4: The historical data indicates a decline from 2.4 to 1.961 in K4, which represents the non-metallic and basic metal industry. This decrease may be attributed to factors such as market competition, shifts in production technology, or changes in consumer preferences impacting this industry. The predicted trend suggests a continuation of this decline, emphasizing the need for strategic interventions to revitalize the non-metallic and basic metal sector. Policymakers and industry leaders should explore avenues for innovation, product diversification, and market expansion (Barrientos, Gereffi & Rossi 2011) to reverse this trend.

K5: The historical data shows an increase from 2.9 to 3.7 in K5, which represents the chemical, pharmaceutical, and fuel processing industry. This growth could be influenced by factors such as escalating demand for chemical products, expansion of the pharmaceutical sector, or advancements in fuel processing. The predicted trend indicates a further increase in K5, signalling potential opportunities

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within this industry. It is crucial for policymakers and industry players to focus on research and development, innovation, and sustainability practices (Salido & Bellhouse 2016) to leverage these opportunities and drive the growth of the chemical, pharmaceutical, and fuel processing sector.

K6: The historical data demonstrates an increase from 0.9 to 1.115 in K6, representing the paper, printing, and media reproduction sector. This growth may be attributed to factors such as advancements in printing technology, rising demand for paper products, or evolving practices in media reproduction. The predicted trend suggests a further in-crease in K6, indicating potential growth prospects within this sector. Policymakers and industry stakeholders should explore strategies to enhance productivity, promote sustainable practices (UNIDO, 2013), and tap into emerging markets to maximize the potential of the paper, printing, and media reproduction industry.

K7: The historical data exhibits an increase from 1.5 to 1.928 in K7, representing the coke, gas, and waste processing industry. This rise could be influenced by factors such as heightened focus on waste management, advancements in gas processing technologies, or environmental regulations driving this industry. The predicted trend suggests a further increase in K7, underscoring the importance of sustainable practices in this sector. Policymakers and industry leaders should prioritize investments in clean technologies, waste management systems (World Bank. 2016), and environmental protection measures to foster the growth of the coke, gas, and waste processing industry while minimizing its environmental impact.

K8: The historical data indicates an increase from 0.5 to 0.9 in K8, representing the electricity, gas, and water sector. This growth could be attributed to factors such as expanding electricity generation capacity, advancements in gas infrastructure, or im-proved water supply systems. The predicted trend suggests a further increase in K8, indicating potential opportunities within this sector. Policymakers and industry stakeholders should prioritize investments in renewable energy sources (United Nations Development Programme. 2015), modernization of infrastructure, and efficient water management practices to drive the growth and sustainability of the electricity, gas, and water sector.

Policymakers, industry leaders, and stakeholders can leverage this knowledge to develop targeted strategies, policies, and interventions that promote sustainable growth, enhance competitiveness, and ensure the inclusive participation of women in these sectors. By addressing the specific needs and constraints faced by women in each industry, it is possible to create an enabling environment where women can benefit from their participation in global value chains and contribute to the overall economic development and empowerment of Indonesia. In summary, the historical

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data and predicted trends for various industries illustrate the dynamic nature of economic sectors in terms of growth, decline, and potential opportunities. These insights can serve as valuable information for businesses, policymakers, and stakeholders, enabling them to make informed decisions and formulate effective strategies to navigate the challenges and capitalize on the prospects within each industry.

It is very important to note that these analyses are based on historical data and pre-dictions, and the actual outcomes may be influenced by a range of macro and microeconomic factors (Cameron & Trivedi, 2009; Gujarati & Porter, 2012), including government policies, market dynamics, technological advancements, and global economic conditions. (Kaplinsky & Readman 2005)

The Genetic Algorithm (GA) with a Mean Square Error (MSE) of 0.011% and Mean Absolute Percentile Error (MAPE) of 2.134% has been proven to explain the phenomenon occurring for k1, k2, k3, k4, k5, k6, k7, and k8 related to the microeconomic aspect, which is largely associated with sectoral economic theories rather than more general or "grand theories" in the context of economics. In this case, we observe changes in different economic sectors and the microeconomic factors that influence them, such as shifts in consumer demand, market competition, changes in production technology, consumer preferences, and environmental regulations. (Gujarati & Porter, 2012)

However, if we want to connect this phenomenon to some broader economic theories, several relevant concepts may include:

Economic Growth Theory: The phenomenon of increase or decrease in specific sectors can be explained through economic growth theories (Kaplinsky & Readman 2005) that identify factors affecting long-term economic growth, such as investment, technological innovation, and capital accumulation (Hiratsuka & Uchida 2010).

International Trade Theory: The phenomenon of increase or decrease in specific sectors can also be understood through international trade theories that study factors influencing economic specialization, comparative advantage, and the flow of trade between countries. (Cameron & Trivedi, 2009).

Economic Development Theory: The phenomenon of changes in economic sectors can be related to economic development theories that study factors influencing a country's economic development, such as institutional factors, human resources, and economic structure. (World Bank. 2016).

CONCLUSION

Women's participation in Global Value Chains (GVCs) plays a crucial role in economic development and women's empowerment. This study utilized a Genetic Algorithm (GA) optimization approach to predict women's participation in GVCs in

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Indonesia. The findings highlighted the significant influence of factors such as education, age, working hours, marital status, number of dependents, and income level on women's involvement in GVC activities.

The results provide valuable insights for policymakers and stakeholders to design targeted interventions that promote women's economic empowerment and increase their participation in GVCs. Enhancing educational opportunities, supporting entrepreneurship, providing family support, increasing financial inclusion, promoting ICT ac-cess, and challenging gender stereotypes are among the recommended policy measures.

By implementing these policies and fostering an enabling environment, Indonesia can unlock the potential of women's participation in GVCs, leading to sustainable economic growth, poverty reduction, and gender equality.

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