



Measuring the impact of non-performing loans on credit-output frontier

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Abstract

This research examines the efficiency of banking sectoral credit in generating economic output in East Java, with a focus on the impact of Non-Performing Loans (NPLs) on the credit-output efficiency frontier. Using quarterly sectoral data from 2012 to 2022 and implementing a stochastic frontier approach, this study decomposes NPLs into two categories: inefficient NPLs, arising from financing inefficiencies, and structural NPLs, originating from inherent credit risk and market risk. Subsequently, a dynamic fixed effects model is employed to test the impact of these decomposed NPLs on credit-output efficiency. The research results indicate that NPLs significantly influence credit efficiency. Inefficient NPLs tend to reduce credit-output efficiency in the short term, while structural NPLs diminish credit-output efficiency in both the short and long term. Based on these findings, enhancing sectoral credit-output efficiency necessitates improving banking risk management to reduce inefficient NPLs and maintaining macroeconomic stability to mitigate structural NPLs. Additionally, efforts to boost credit-output efficiency should focus on Gross Regional Domestic Product (GRDP) main sectors, such as manufacturing, trade, and logistics. Macroprudential incentives could be provided to banks that extend credit to priority sectors and exhibit low levels of inefficient NPLs. Concurrently, fiscal policy should aim to expand economic scale through infrastructure development, tax incentives, and accelerated technology adoption.

Keywords: credit-output efficiency; inefficient NPLs; structural NPLs

Introduction

Bank credit plays a pivotal role as a crucial component of aggregate demand in the post-Keynesian perspective (Lavoie, 2022). As the primary mechanism for creating money within the economy, bank credit significantly enhances the spending power of the private sector (McLeay et al., 2014; Werner, 2014). Furthermore, it serves as a vital instrument enabling firms to overcome internal capital constraints and seize investment opportunities that boost productivity and drive business expansion (Ayyagari et al., 2011; T. Beck et al., 2005). Moreover, broader access to credit can improve income distribution by providing financing to firms in non-priority sectors (T. Beck & Levine, 2004). Consequently, credit can foster a more inclusive and equitable economic environment, ultimately benefiting the economy.

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Drawing on the concept of stock and flow, expenditure in one sector translates to income for other sectors, underscoring that efficiency in a single sector impacts the entire economy (Godley & Lavoie, 2016). Therefore, within the framework of representative firms, credit efficiency is recognized as a multifaceted concept. It is not solely measured by the optimal allocation of resources but also by its impact on economic growth, stability, and equity (Minsky, 2016; Rothschild & Stiglitz, 1976). This study, grounded in the concept of stock and flow and the critical importance of credit efficiency, analyzes how credit efficiency drives sectoral aggregate output. For technical reason, the term “credit-output efficiency” is employed to gauge the efficacy of bank credit in propelling aggregate output. Specifically, the level of credit-output efficiency in a sector is determined by how closely the actual level of credit-output efficiency approaches its potential efficiency (frontier). In this study, potential output is estimated using the stochastic frontier approach (Aigner et al., 1977; Hughes & Moon, 2022).

Furthermore, this study also investigates the factors influencing credit-output efficiency. According to Louzis et al. (2012), one major consequence of suboptimal credit in stimulating growth is the prevalence of Non-Performing Loans (NPLs). Zuhroh et al. (2022) contends that NPLs are endogenous and coexist with credit distribution, making their complete elimination nearly impossible. Therefore, prudent management of NPLs is paramount. Unlike Louzis et al. (2012), which merely regresses NPLs against growth, this study, building on Hughes & Moon (2022), decomposes NPLs into two categories: NPLs arising from financing inefficiencies (inefficient NPLs) and Structural NPLs. Structural NPLs include NPLs from inherent credit risk (Inherent NPLs) and NPLs resulting from market risk (Market risk NPLs). Inefficient NPLs indicate internal issues such as poor risk management or inaccurate credit assessments, whereas Structural NPLs reflect credit risk associated with loan size and market risk. This innovative approach positions this study as a pioneer in decomposing NPLs within a sectoral framework.

The decomposition of NPLs facilitates more targeted policy formulation. If credit-output efficiency is predominantly influenced by internal factors, solutions may involve enhancing risk management capacity in banking or implementing regulatory reforms (Alhammadi et al., 2020; Hall et al., 2023; Ugoani, 2015). Conversely, if market risk primarily affects credit efficiency, necessary interventions might include monetary or fiscal policies to stabilize the economy (Borio, 2014; Yuli & Rofik, 2023b). Additionally, this study’s approach enables more accurate risk assessments. Banks can refine their strategies to better manage risks by understanding whether the primary risks are internal or external. Comprehending both the source of risk and the aggregation of risk by sector aids in allocating resources to optimize credit-output efficiency while mitigating risks.

East Java, as Indonesia's second-largest provincial economy, is characterized by a highly diverse economic structure. Its key sectors include agriculture, manufacturing, trade, and logistics, each contributing uniquely to regional growth (Rofik & Magdalena Golec, 2022; Tika Meilaningsih & Widya Yuniastuti, 2022). This diversity highlights the strategic role of sector-specific credit allocation in addressing distinct financing needs and leveraging growth opportunities. The region’s heavy reliance on agriculture and manufacturing also underscores the importance of understanding the relationship between sectoral credit-output efficiency and economic performance. However, the existing literature often focuses on the general relationship between credit and economic growth in the region (Nufus et al., 2021; Rofik et al., 2023), without adequately addressing critical factors such as credit-output efficiency and the uncertainties posed by inefficient credit and market risks. This oversight is largely due to the dominant neoclassical economic framework, which prioritizes equilibrium in the money and goods markets, often at the expense of exploring more nuanced aspects like credit optimization and risk management.

This paper argues for a paradigm shift in the analysis of banking's role in economic growth in East Java. By moving beyond traditional models, it seeks to fill a critical gap in the literature, the need to optimize bank credit's contribution to growth through a comprehensive examination of sectoral credit-output efficiency. The study not only aims to identify the efficiency of credit allocation across sectors but also delves into the sources of NPLs, analyzing how different components of these loans impact overall efficiency. By proposing a strategy that decomposes NPLs to better understand their origins and effects, this research offers a novel approach to enhancing the role of bank credit in maximizing sectoral growth potential in East Java. This methodological innovation promises to contribute significantly to the formulation of more targeted and effective policy strategies, ultimately driving more sustainable economic development in the region.

The structure of this paper is as follows: The literature review section elucidates perspectives on credit efficiency, NPL decomposition, and the theoretical foundation regarding the impact of NPLs on credit efficiency. The methodology section details the data and methods used to determine efficiency, classify NPLs, and the model employed to assess the effect of NPLs on credit efficiency. The results and discussion section presents the study's main findings, comparisons with related theories and research, and

a synthesis of these insights. Finally, the conclusion summarizes the study's objectives, methods, findings, and implications.

Literature Review

The Role of Banking Credit in Post-Keynesian Economics

Bank credit plays a crucial role in post-Keynesian economics, which emphasizes aggregate demand as a primary driver of economic growth. Increased bank credit to both businesses and households directly boosts aggregate demand. Consumption and investment, major components of aggregate demand, are facilitated by access to credit. Godley & Lavoie (2016); and Zuhroh et al. (2022) demonstrates that bank-issued credit stimulates economic activity by enhancing consumption and investment capacities. This aligns with Minsky's view that credit not only boosts consumption and investment initially but also triggers a multiplier effect that propels the entire economy. Expanded credit availability generates jobs, income, and demand, thereby reinforcing the economic cycle (Minsky, 2016).

Moreover, bank credit functions not only as a funding mechanism but also as a crucial tool for mitigating uncertainty and promoting long-term economic growth. Keen (2014) asserts that effective demand, bolstered by credit, is pivotal for achieving dynamic economic equilibrium. Bank credit provides companies with the flexibility to pursue investment opportunities that enhance productivity and expand operations. Additionally, broader credit access contributes to better income distribution, fostering a more inclusive and equitable economic environment (Keen, 2014; Woodford, 2022). The multiplier effect of credit ensures that initial investments yield greater economic growth than the initial amount invested, thereby catalyzing broader economic expansion. Research by Gertler & Gilchrist (1994) underscores that economic sectors with better access to bank credit tend to experience accelerated growth rates. This underscores the critical role of bank credit in driving aggregate demand. In the context of post-Keynesian economics, the importance of bank credit in stimulating aggregate demand and initiating multiplier effects underscores that policies supporting credit access can be potent tools for fostering inclusive and sustainable economic growth. Effective credit policies not only stimulate present consumption and investment but also fortify the economic foundation for future growth, perpetuating a sustainable cycle of rising demand, production, and income (Lavoie, 2022; Woodford, 2022).

The post-Keynesian approach to economics diverges from neoclassical theory by prioritizing effective demand dynamics, uncertainty, and income distribution over allocative efficiency and perfect markets. Within this framework, bank credit assumes a pivotal role as a tool to overcome internal capital constraints within firms. Access to sufficient credit empowers businesses to seize investment opportunities, thereby enhancing productivity and expanding operations, which in turn fuels overall economic growth. Beyond mere funding, credit also mitigates uncertainties businesses face when making investment decisions (T. Palley, 2021; Werner, 2014).

Broadly speaking, expanded credit access serves as a potent instrument for improving income distribution and fostering a more inclusive economy. In the post-Keynesian view, effectively distributed credit across various sectors—including households and small to medium enterprises—can mitigate economic inequality (T. Palley, 2021). By extending credit access, particularly to marginalized groups lacking access to traditional capital markets, the banking sector can contribute significantly to overall economic prosperity. The multiplier effect stemming from increased consumption and credit-driven investments generates additional demand, leading to heightened employment opportunities and income growth across diverse sectors (T. Beck et al., 2005; Gertler & Gilchrist, 1994).

Moreover, empirical research underscores the profound impact of enhanced credit access on economic inclusivity. For instance, studies like Levine (2005) highlight that inclusive financial systems correlate with reduced income inequality and sustained long-term economic expansion. This underscores the critical role of bank credit in fostering equitable and sustainable economic growth. In the post-Keynesian framework, credit efficiency transcends resource allocation efficiency to encompass its broader impacts on economic stability and equitable income distribution. Strategically managed credit policies lay the groundwork for a robust and fair economy that benefits society at large (T. Beck et al., 2005; T. I. Palley, 2016; Yuli & Rofik, 2023a).

Credit Efficiency in Sectoral Context

Bank credit plays a pivotal role in the economy, and its efficiency in driving aggregate output merits special attention. In macroeconomic theory, credit efficiency not only influences sectors directly

receiving credit but also impacts the entire economy through a circular flow mechanism. Lavoie (2022) explain that expenditures in one sector become income for others, creating a chain of economic influence. Thus, efficient credit allocation in one sector can enhance productivity and demand across various sectors, bolstering aggregate economic growth (Jin et al., 2011; Lavoie, 2022).

Credit-output efficiency is a complex concept encompassing optimal resource allocation and broader impacts on growth, stability, and equity. Mishkin (2007) underscores that efficient credit allocation fosters economic growth by ensuring funds are available for productive investments. Moreover, it enhances economic stability by mitigating credit risks and reducing financial system uncertainties. Improved credit efficiency also promotes economic inclusivity by expanding credit access to diverse societal and economic segments previously marginalized from financial markets (Mishkin, 2007; Rofik & Magdalena Golec, 2022).

However, inefficiencies in credit allocation can detrimentally affect economic performance. Berger & DeYoung (1997) found that banks with high NPL levels often exhibit operational inefficiencies, hindering overall economic growth. Therefore, understanding factors influencing credit efficiency—such as risk management and banking policies—is crucial. Policies supporting efficient credit allocation can maximize banking credit's positive impact on sustainable economic growth and stability (Mileris, 2015).

Inefficient credit allocation exacerbates the output gap, the disparity between actual and potential economic output. Bernanke and (Bernanke & Gertler, 1989) assert that suboptimal credit distribution hampers achieving potential output, widening the output gap. When credit isn't optimally directed, productive sectors may lack sufficient funds for investment and expansion, curtailing overall economic growth potential (McLeay et al., 2014).

Research indicates that high NPL levels, reflecting poor credit risk management and fund distribution, contribute to credit-output inefficiencies (Gajurel, 2023; Kashian et al., 2019). These inefficiencies diminish investment capacity and heighten economic uncertainty, eroding investor and consumer confidence. Elevated NPL burdens constrain banks from providing new credit, exacerbating the output gap and hindering long-term economic growth.

Furthermore, Stiglitz & Weiss (1981) note that asymmetric information and flawed credit market selection can lead to inefficient fund allocation, hindering optimal economic growth. Enhancing credit efficiency through improved risk management and transparency is vital to directing funds towards the most productive sectors. This approach aligns actual output closer to potential output, narrowing the output gap and fostering sustainable economic growth (Louzis et al., 2012; Mishkin, 2007).

Research Method

Credit-Output Efficiency

A primary challenge is isolating GRDP components not derived from bank credit. To address this, the study takes several steps. Initially, it estimates the expected contribution of banking financing to GRDP in East Java, denoted as $E((\bar{g}|GRDP)) = g$, $0 \leq \bar{g} \leq 1$. The average banking financing contribution to GRDP in each sector, \bar{g} is approximated using the elasticity coefficient of banking financing to GRDP as outlined in Equation (1).

$$\log(GRDP) = k + \beta * \log(Credit) + e \quad (1)$$

Once β is determined, the proportion of GRDP from bank credit is calculated according to Equation (2) and equation (3) demonstrates how GRDP expectations are generated from banking credit.

$$\bar{g} = \frac{1}{GRDP} \beta * \log(Credit) \quad (2)$$

$$E(g_i|GRDP) = g_i = \bar{g} * GRDP_i \quad (3)$$

After estimating g , the study proceeds to evaluate credit efficiency using a Stochastic Frontier approach, as described in Equation (4).

$$g_i = \alpha_0 + \alpha_1(credit_i) + \varepsilon_i \quad (4)$$

The Frontier function, outlined in Equation (5), determines the optimal efficiency level, which is further detailed in Equation (6).

$$\text{Best practice or frontier } g_i = \alpha_0 + \alpha_1(credit_i) \quad (5)$$

$$\text{Credit-output efficiency} = g_{aktual} - (\alpha_0 + \alpha_1(credit_i) - E(v_i|\varepsilon_i)) - E(u_i|\varepsilon_i) \quad (6)$$

Decomposing NPLs

We follow Hughes & Moon (2022) with some minor algebraic manipulation. NPLs are modeled as a function of credit, as shown in equation (7). Efficiency estimates are derived from equation (8), and statistical noise is represented by equation (9).

$$NPLs_i = \alpha_1(credit_i) + \varepsilon_i + \alpha_0 \quad (7)$$

$$Inefficient\ NPLs_i = E(u_i|\varepsilon_i) \quad (8)$$

$$Statistical\ Noise_i = E(v_i|\varepsilon_i) = \varepsilon_i - E(u_i|\varepsilon_i) \quad (9)$$

The actual NPLs are explained by equation (10). Therefore, the inefficiency of NPLs is described by equation (11), which reduces actual NPLs by the structural NPLs defined in equation (12).

$$NPLs_i = \alpha_0 + \alpha_1(credit_i) + E(u_i|\varepsilon_i) + E(v_i|\varepsilon_i) \quad (10)$$

$$Inefficient\ NPLs_i = (E(u_i|\varepsilon_i)) = NPL_i - [\alpha_1(credit_i) + E(v_i|\varepsilon_i)] - \alpha_0 \quad (11)$$

$$Structural\ NPLs = [\alpha_1(credit_i)] + E(v_i|\varepsilon_i) + \alpha_0 \quad (12)$$

Structural NPLs are further decomposed into two components: NPLs arising from inherent risk, following equation (13), and NPLs resulting from market risk, defined by equation (14).

$$Inherent\ NPLs_i = \alpha_1(credit_i) \quad (13)$$

$$Market\ risk\ NPLs = E(v_i|\varepsilon_i) + \alpha_0 \quad (14)$$

Dynamic Fix Effect

This study assumes that the long-run and short-run parameters are homogeneous across entities in the panel. This is because banking and related economic sectors operate within the same regulatory system and monetary policy. Consequently, this study employs the Dynamic Fixed Effects (DFE) model. DFE is simpler than Pooled Mean Group (PMG) and Mean Group (MG) models because it does not require accounting for complex heterogeneity among entities. This simplicity makes the model easier to interpret, and the results are more directly applicable to policy formulation (Pesaran et al., 1999; Pesaran & Smith, 1995).

Additionally, by assuming homogeneity, DFE can provide more efficient estimates and reduce the variance of parameter estimates, thereby increasing confidence in the model results. DFE also controls for unobserved heterogeneity using fixed effects, which eliminates bias caused by unmeasured but time-constant variables for each entity. This ensures that the estimated relationship between NPLs and credit efficiency is not influenced by unobserved factors.

To capture the influence of long-run impacts, this study uses the ARDL model with fixed effects as specified in equation (15). To capture the short-term effects and their adjustments to the long-term effects, this study applies an error correction model, also represented in equation (16). The model is

estimated using Maximum Likelihood Estimation (MLE).

$$y_{it} = \alpha_i + \sum_{j=1}^p \phi_j y_{i,t-1} + \sum_{k=0}^q \beta_k X_{i,t-k} + \varepsilon_{it} \quad (15)$$

$$\Delta y_{it} = \alpha_1 + \lambda(y_{i,t-1} + \theta X_{i,t-1}) + \sum_{j=1}^{p-1} \phi_j \Delta y_{i,t-1} + \sum_{j=0}^{q-1} \beta_k \Delta X_{i,-j} + \varepsilon_{it} \quad (16)$$

Notes:

y_{it} is the dependent variable

$X_{i,t-k}$ is a vector for explanatory variables.

α_i is a fixed effect that captures heterogeneity between groups.

ϕ_j is coefficient of the dependent variable

β_k is the lag coefficient of the dependent variable

ε_{it} is error term

Δy_{it} is the first different of the dependent variable

$\Delta X_{i,-j}$ is the first different vector of the independent variables

λ is the error correction term which shows the adjustment towards long-term equilibrium

$y_{i,t-1} + \theta X_{i,t-1}$ is a long-term equilibrium that shows deviations from long-term equilibrium

i represents cross section

t represent time

Control Variable(s)

Economies of Scale

Economies of scale denote the relative size of a specific economic sector within the overall economy as follows equation (17). In assessing credit-output efficiency, it's essential to control for economies of scale to mitigate biases arising from sector size differences (Zongli et al., 2017).

$$Scale = \frac{GRDP_{it}}{GRDP_t} \quad (17)$$

Financial Depth

Financial depth indicates the extent to which an economic sector relies on bank credit to support its operations (Rofik & Magdalena Golec, 2022; Zuhroh & Malik, 2023). The credit-to-GRDP ratio as formulated in equation (18) is a critical metric influencing credit availability and quality. Higher ratios can exacerbate Non-Performing Loan (NPL) issues and reduce credit efficiency. Controlling for financial depth helps isolate the impact of credit levels on sectoral credit efficiency, independent of other factors.

$$Financial\ depth = \frac{Credit_{it}}{GRDP_{it}} \quad (18)$$

Sectoral Business Cycles

Sectoral business cycles reflect economic fluctuations—from expansion to contraction—experienced by different sectors (Ludvigson et al., 2021; Rofik et al., 2023). Including these cycles as control variables in NPL and credit efficiency analyses ensures a nuanced evaluation across sectors. By adjusting for business cycles, we can assess NPL effects on credit efficiency accurately, accounting for sector-specific economic conditions.

The Hodrick-Prescott (HP) filter decomposes Gross Regional Domestic Product (GRDP) data into trend and cyclical components. The filter's parameter, λ , typically around 600 for quarterly data, controls the smoothness of the trend component. This decomposition helps separate long-term trends from short-term fluctuations, providing a clearer understanding of economic dynamics and aiding in sectoral comparisons (Gertler & Gilchrist, 1994; Ludvigson et al., 2021). The HP filter separates the time series data of Sectoral GRDP (g_{it}) into trend component τ_t and cyclical component c_t as shown in Equation (19), and then minimizes Equation (20).

$$g_{it} = \tau_{it} + c_{it} \quad (19)$$

$$\min_{\tau_{it}} \left(\sum_{t=1}^T (g_{it} - \tau_{it})^2 + \lambda \sum_{t=2}^{T-1} ((\tau_{it+1} - \tau_{it}) - (\tau_{it} - \tau_{it-1}))^2 \right) \quad (20)$$

Robustness test

To test the robustness of the relationship between decomposed NPL and credit-output efficiency, this study also use wavelet analysis. Wavelet transforms enable the identification of temporal and frequency relationships between these variables, providing deeper insight into dynamics that may not be detected by traditional analysis methods (Dimitriou et al., 2020; Kenourgios et al., 2019; Papadamou et al., 2021). Using wavelet plots, we can evaluate the coherence between decomposed NPLs and credit-output efficiency at various time scales, as well as identify significant periods where the relationship is strongest or weakest.

This approach provides an additional analytical dimension that supports the validity and reliability of this study's findings.

Data

This study categorizes economic sectors into nine categories based on data from BPS Statistics Indonesia and the Financial Services Authority, as shown in Table 1. Furthermore, this study uses quarterly data from 2012 until 2022. All credit-related data are extracted from Indonesian banking statistics provided by the Financial Services Authority, while data related to GRDP are sourced from BPS Statistics Indonesia.

Results and Discussion

Credit-Output Efficiency

Figure 1 illustrates that, on average, the manufacturing and trade sectors made the largest contributions to East Java's GRDP from 2012 to 2022. These sectors are also the second and third highest recipients of bank credit, following the household sector. Notably, among the top three recipients of bank credit, only the household sector ranks in the top three for credit-output efficiency, specifically in second place after the energy sector. In contrast, the manufacturing sector ranks seventh, and the trade sector ranks fifth in credit-output efficiency. Furthermore, the top three sectors with the highest credit efficiency, excluding the household sector, include the real estate sector and the energy sector. Interestingly, these two sectors contribute the least to GRDP. In terms of credit receipts, the real estate sector ranks seventh, and the energy sector ranks eighth.

These findings indicate that while high credit distribution in a sector generally correlates with its contribution to GRDP, there is an inverse relationship between high credit distribution and credit-output efficiency. Therefore, enhancing the credit-output efficiency in the manufacturing and trade sectors could significantly boost GRDP. This is particularly important since these sectors are among the top three recipients of bank credit and major contributors to East Java's GRDP.

Table 1. Sectoral classification

No	Sector(s)	Description
1	Agriculture	Agriculture, forestry, fisheries
2	Mining	Mining and excavation
3	Manufacture	Manufacturing industry
4	Energy	Electricity, gas and water
5	Construction	Construction
6	Trade	Wholesale and retail trade
7	Logistic	Provision of accommodation, provision of food and drink, transportation, warehousing and communication
8	Real Estate	Real estate, rental business and corporate services
9	Household	Household and other services

Our study also found that the three sectors with the largest credit distribution—namely the household sector, manufacturing, and trade—consistently rank among the top three sectors with the highest levels of NPLs, both inefficient NPLs and structural NPLs. Conversely, the three sectors with the lowest credit distribution—the real estate sector, energy sector, and mining sector—occupy the bottom three positions in terms of both inefficient and structural NPLs. Additionally, excluding the household sector from the top three sectors with the highest credit-output efficiency, the energy sector and mining sector also emerge as the sectors with the lowest inefficient NPLs and structural NPLs. The findings indicate that NPLs, both inefficient and structural, are not only directly proportional to the level of credit distribution but also aligned with the level of credit-output efficiency.

Trend of NPLs

From a trend perspective (see Figure 2), it can be observed that inefficient NPLs exhibit higher volatility than structural NPLs. While structural NPLs are relatively more stable, they tend to follow a long-term trend. We argue that the high volatility of inefficient NPLs reflects banks' inability to accurately assess credit risk and manage credit portfolios effectively. Factors such as weak credit granting procedures, lack of in-depth risk analysis, and inadequate supervision contribute to fluctuations in inefficient NPLs (Gajurel, 2023; Kashian et al., 2019). Studie also highlighted that banks with robust risk management frameworks and stringent credit assessment protocols tend to have lower levels of inefficient NPLs (R. Beck et al., 2021;

Ghosh, 2015).

Rank	GRDP Contribution	Outstanding Credit Ratio	Inefficient NPLs (%)	Structural NPLs (%)	Efficiency Credit-Output (%)
1	Manufacture 0.305	Household 0.314	Trade 1.962	Household 1.532	Energy 94.7
2	Trade 0.189	Trade 0.265	Manufacture 1.885	Trade 1.459	Household 93.6
3	Logistic 0.144	Manufacture 0.255	Household 1.866	Manufacture 1.458	Mining 93.4
4	Agriculture 0.114	Logistic 0.043	Construction 1.656	Agriculture 1.261	Agriculture 93.4
5	Construction 0.094	Agriculture 0.042	Logistic 1.481	Logistic 1.225	Trade 93.0
6	Household 0.079	Construction 0.042	Agriculture 1.405	Construction 1.213	Construction 92.9
7	Mining 0.050	Real Estate 0.023	Real Estate 1.303	Real Estate 1.151	Manufacture 92.8
8	Real Estate 0.017	Energy 0.009	Mining 0.976	Energy 1.075	Real Estate 92.6
9	Energy 0.004	Mining 0.003	Energy 0.124	Mining 0.902	Logistic 91.7

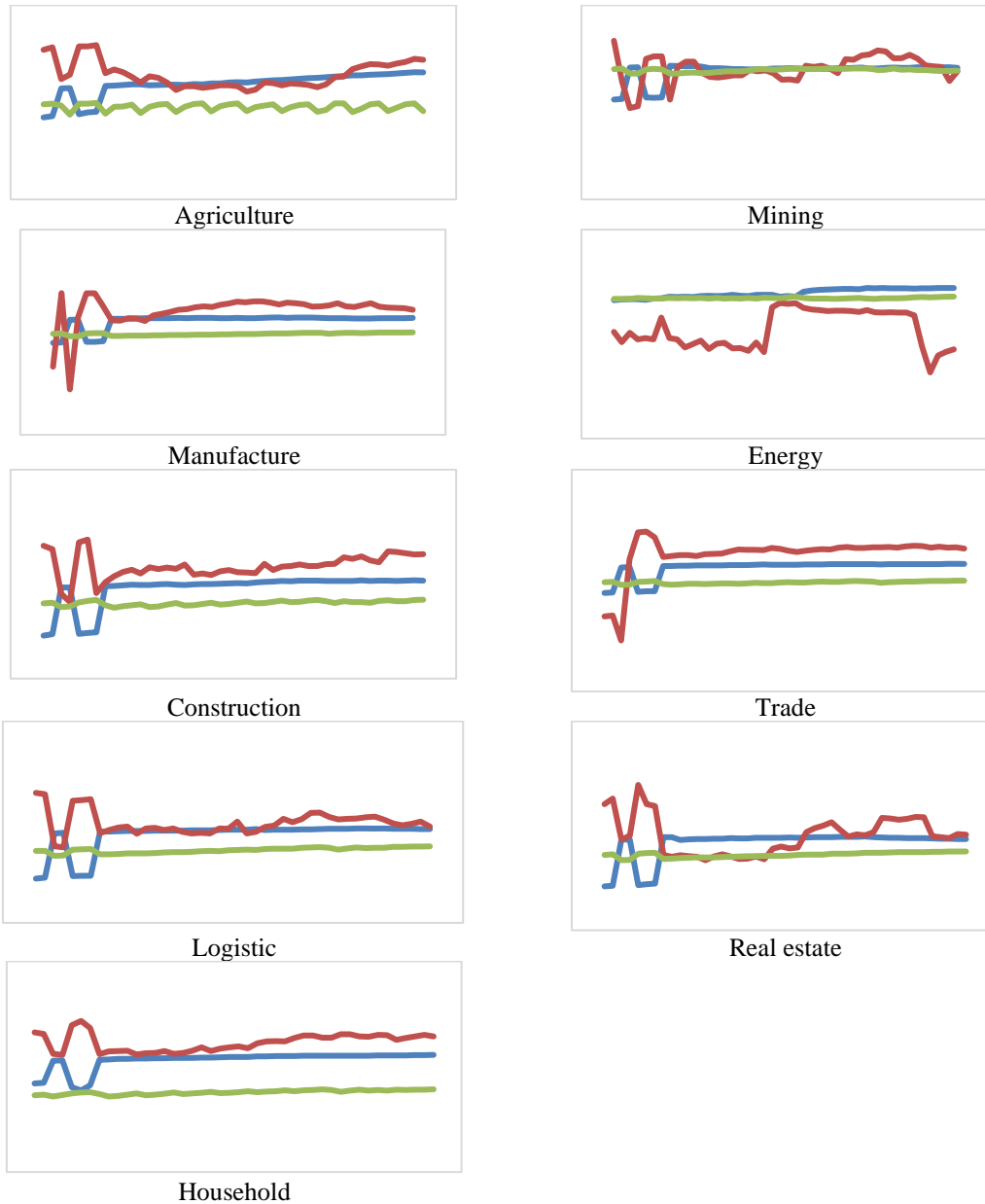
Notes: Each category is sorted in descending order, from largest to smallest.

Figure 1. Average sectoral ranking during the observation period (2012-2022) based on several selected categories

In contrast, the relative stability but long-term trend of structural NPLs is likely due to the persistence of inherent credit risk and the slow-changing nature of structural NPLs. For instance, central bank interest rate adjustments aimed at reducing inflation can have a long-term impact on increasing non-performing loans. This is particularly evident in periods of economic downturn, where macroeconomic factors such as declining GDP and rising unemployment rates exacerbate structural credit risks (Mileris, 2015; Morakinyo et al., 2018). A recent study by Ahmed et al. (2021) found that structural NPLs are significantly influenced by macroeconomic variables, indicating the importance of economic stability in managing structural credit risk.

Further, the literature suggests that while inefficient NPLs are more sensitive to bank-specific factors (Gajurel, 2023; Hughes & Moon, 2022; Kashian et al., 2019), structural NPLs are predominantly driven by broader economic conditions (Ahmed et al., 2021; Mileris, 2015; Morakinyo et al., 2018). This distinction underscores the necessity for banks to implement comprehensive risk management strategies that address both internal inefficiencies and external economic risks. For instance, improving internal credit assessment processes and strengthening supervision can mitigate the volatility of inefficient NPLs, whereas macroeconomic stabilization policies can help manage structural NPLs over the long term.

Proportionally, data indicates that the energy sector has an exceptionally high proportion of structural NPLs. This suggests that most credit problems in this sector stem from inherent credit risk and market risk NPLs. In contrast, the other eight sectors have a proportion of structural NPLs below 50%, indicating that internal banking factors or inefficient NPLs are more dominant. The manufacturing and trade sectors rank second and third, respectively, in terms of the highest proportion of inefficient NPLs, following the household sector, which has the highest level of inefficient NPLs. These findings highlight those internal challenges, such as poor risk management and suboptimal operations, are the predominant sources of NPLs in all sectors except the energy sector.



Notes:

- Inefficient NPLs
- Structural NPLs
- Credit-Output efficiency

Figure 2. Trends in Inefficient NPLs and Structural NPLs from 2012 until 2022

The impact of decomposed NPL on credit-output efficiency

Based on the analysis using the Dynamic Fixed Effects (DFE) model, it can be observed that inefficient NPLs reduce the level of credit-output efficiency in the short term. However, in the long term, the impact of NPLs arising from financing inefficiencies is not significant. This finding suggests that the influence of inefficient NPLs gradually diminishes over time. This result is plausible because banks can potentially control inefficient NPLs through internal adjustments such as improving risk management, enhancing credit granting procedures, and adopting technology to reduce inefficiencies (Ghosh, 2015; Jakubík & Reiningger, 2013).

On the other hand, structural NPLs have a significant negative impact on credit-output efficiency both in the short and long term. In the short term, increases in NPLs caused by market risks—such as

inflation, rising interest rates, or instability—can immediately disrupt the financial health of debtors (Mileris, 2015; Morakinyo et al., 2018). Generally, these shocks cannot be resolved quickly, so their effects are felt not only in the present but also in the future. For instance, the disruption caused by social restrictions during the COVID-19 outbreak directly impacted the cash flow of businesses, increasing the potential for default (Ahmed et al., 2021). The impact of NPLs generated during the pandemic continues to be felt today.

Another scenario involves sudden increases in interest rates, which not only raise borrowing costs but also decrease purchasing power (Louzis et al., 2012). Debtors who were previously able to make timely payments may start struggling to meet their obligations due to reduced income and higher debt burdens. Additionally, rising interest rates can depress the prices of stocks, bonds, and other asset classes. When asset prices depreciate, the ability of debtors to repay loans is also affected, leading to an increase in loan defaults and bank NPLs (Messai & Jouini, 2013). Therefore, it is rational to conclude that structural NPLs, which encompass inherent credit risk and market risk, disrupt credit-output efficiency in both the short and long term.

Table 2. Result of dynamic fix effect

Variable(s)	Model 1		Model 2	
	Coefficient	p-value	Coefficient	p-value
	Long term			
Inefficient NPLs	0.025	0.115	0.023	0.137
Structural NPLs	-0.066**	0.013	-0.079***	0.007
Economic scale	0.242**	0.039	0.296	0.278
Credit dept			0.007	0.354
Business cycle	0.004	0.163	0.004	0.135
	Short term			
Error correction	-0.049***	0.000	-0.051***	0.000
Inefficient NPLs	-0.001*	0.076	-0.001*	0.094
Structural NPLs	-0.131***	0.000	-0.129***	0.000
Economic scale	0.924***	0.000	0.920***	0.000
Credit dept			-0.0007	0.375
Business cycle	0.005***	0.000	0.005***	0.000
Constanta	0.048***	0.000	0.050***	0.000

Notes: ***, **, * significant at 1%, 5%, and 10%, respectively.

The impact of these differences in NPL decomposition has important implications for credit risk management strategies and banking policies. Banks need to strengthen risk management and credit granting procedures to reduce lending inefficiencies (R. Beck et al., 2021; Ghosh, 2015). Measures such as enhancing training for credit analysts, adopting advanced technology for risk analysis, and improving internal supervision can be implemented to improve financing efficiency (Ghosh, 2015). Additionally, reducing dependence on sectors vulnerable to market fluctuations through credit portfolio diversification can help mitigate the long-term negative impacts of structural NPLs, particularly those arising from market risk (Jakubík & Reininger, 2013).

Wavelet plot

The wavelet plot, as shown in Figure 3, reveals that inefficient NPLs for each sector have a high heatmap color at low time frames, indicating that credit-output efficiency and inefficient NPLs have high coherence in the short term. Meanwhile, for the relationship between structural NPLs and credit-output efficiency, high heatmaps tend to occur at higher intervals, while at lower intervals, high heatmaps are not as intensive as in the relationship between inefficient NPLs and credit-output efficiency. Thus, this wavelet plot confirms the results of DFE, which shows that inefficient NPLs have an impact only in the short term, while structural NPLs have an impact in both the short and long term.

Emphasis on leading sectors

The Manufacturing and Trade sectors are the two top contributors to the East Java economy. However, these sectors consistently rank in the top three for both inefficient NPLs and structural NPLs. Additionally, neither sector is among the top three in terms of credit-output efficiency. This suggests that

if NPLs—both inefficient and structural—can be reduced, the output gap in these sectors would decrease.

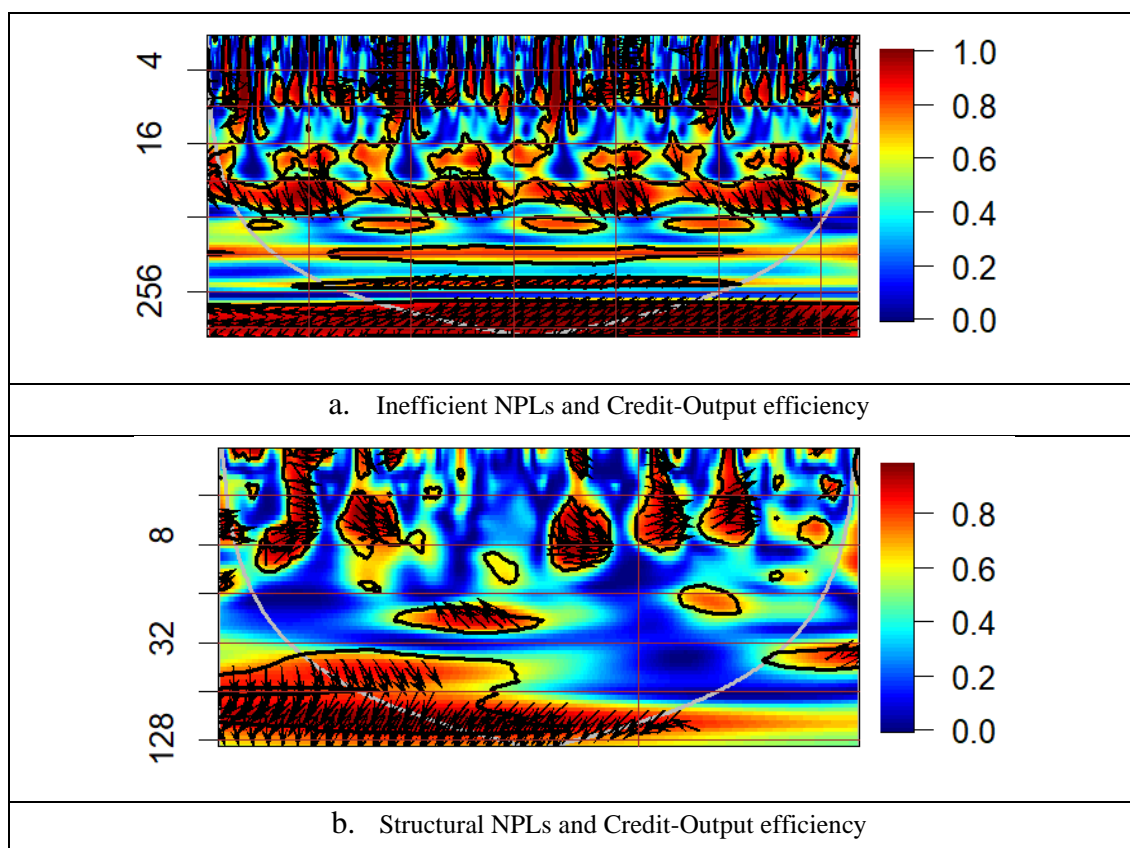


Figure 3. Wavelet Plot

Furthermore, the Logistics sector has the third highest GRDP contribution after the Manufacturing and Trade sectors, but its credit-output efficiency is the lowest among the nine sectors analyzed. This indicates significant untapped potential. Factors contributing to this inefficiency may include a lack of innovation, inadequate infrastructure, and management and operational challenges within the sector (Louzis et al., 2012; Rofik & Magdalena Golec, 2022; Yuli & Rofik, 2023a). Consequently, bank credit has not achieved its potential output in the logistics sector.

Impact of control variable(s)

The study found that larger sectoral economies of scale, measured by the ratio of sector GRDP to total GRDP, tend to boost credit-output efficiency. This finding aligns with economic theory, which states that sectors with significant economic contributions tend to have better access to financial resources, including credit (Rofik & Magdalena Golec, 2022; Zuhroh & Malik, 2023). Larger sectors typically possess more mature structures, superior risk management, and the ability to generate stable cash flows, all contributing to increased credit efficiency. According to the theory of economies of scale, firms or sectors operating on a large scale can exploit operational efficiencies and synergies, thereby enhancing productivity and reducing costs per unit of production.

The study also found that sectoral business cycles positively impact credit-output efficiency. Sectoral business cycles, referring to economic fluctuations at the sectoral level, can influence the availability and utilization of credit. When specific sectors are in an expansionary phase, they typically exhibit higher demand for credit to finance investment and growth, which in turn can enhance credit-output efficiency. In economic theory, this corresponds to the understanding that a healthy business cycle fosters conditions conducive to productive investment, increasing production capacity and overall economic efficiency.

Meanwhile, the research findings indicate that credit depth does not significantly impact credit-output efficiency, suggesting there is no evidence of over-financing. This implies that the banking sector in East Java still has room to increase credit growth without compromising efficiency. Therefore, policies promoting credit growth remain relevant and necessary to achieve maximum capacity.

Policy recommendation

Monetary and macroprudential

Consider to structural NPLs that indicate has neither short and long-term impact on credit-output inefficiency, macroeconomic stability must be maintained by controlling inflation and ensuring exchange rate stability (Ahmed et al., 2021; Morakinyo et al., 2018). Central banks can use various monetary instruments, such as open market operations, interest rate adjustments, and foreign exchange market interventions, to achieve these goals. This approach helps guarantee macroeconomic stability, thereby creating a more conducive environment for economic growth.

Furthermore, in the current high-interest rate regime, central banks must pursue appropriate policies to ensure economic stability and sustainable growth. One approach is to maintain the policy of reducing the Statutory Reserve for banks that actively distribute credit to key sectors such as manufacturing, trade, and logistics. This policy is designed to increase banking liquidity, providing more funds to finance sectors with significant potential for driving economic growth.

Financial Services Authority

Given the significant impact of inefficient NPLs on short-term credit-output efficiency, the Financial Services Authority must implement strategic measures to bolster risk management and lending practices. By enforcing stricter regulations on credit risk management, the Authority can mitigate inefficiencies and reduce the risk of NPLs. Such regulations will compel banks to conduct more rigorous risk assessments before extending credit, thereby minimizing potential losses (Hughes & Moon, 2022; Kashian et al., 2019).

In addition, promoting the adoption of financial technology (fintech) offers a promising solution for enhancing risk assessment and credit processes. Fintech can streamline and expedite the risk evaluation process, allowing banks to make more accurate and timely credit decisions (Bussmann et al., 2020; Yuli & Rofik, 2023b). Authorities should incentivize banks to invest in technology that supports operational efficiency and risk management. These incentives might include tax breaks, subsidies, or more flexible regulatory support for the implementation of new technologies.

Fiscal Policy

The government plays a crucial role in developing infrastructure that supports sectoral credit-output efficiency. Investments in transportation infrastructure such as roads, ports, and airports are vital for the logistics sector. Modern and efficient infrastructure facilitates the flow of goods and services, reduces logistics costs, and enhances national competitiveness. Additionally, building modern and efficient storage facilities is essential to support logistics sector operations. Advanced warehouse facilities enable better storage and management of goods, reduce waiting times, and minimize results in smoother and more efficient logistics sector operations.

Also, to promote credit-output efficiency in the manufacturing, trade, and logistics sectors, the government might provide tax incentives for investment in technology and innovation. These tax incentives will encourage companies to adopt new technologies that can increase productivity and operational efficiency (Daniel & Faustin, 2019; Malik et al., 2021). For instance, automation of production processes, the use of sophisticated supply chain management systems, and the application of information technology in daily operations. Beyond tax incentives, the government can also consider providing subsidies for the adoption of new technologies that improve operational efficiency. These subsidies can help companies cover some of the costs associated with investing in advanced technology, thereby encouraging innovation and increased efficiency.

Conclusions, suggestions and limitations

Our study challenges conventional perspectives on the role of NPLs in the banking sector of East Java, offering a critical assessment of their impact on the credit-output efficiency frontier. By employing a stochastic frontier approach and a dynamic fixed effects model, we expose the dual nature of NPLs, categorizing them into inefficient NPLs—stemming from financing inefficiencies—and structural NPLs—rooted in fundamental credit and market risks. Our findings are provocative: both types of NPLs not only

undermine credit efficiency but do so with distinct temporal dynamics. Inefficient NPLs erode credit-output efficiency in the short run, while structural NPLs exert a corrosive influence over both short and long-term periods.

These results underscore a glaring oversight in current banking practices and macroeconomic policies. The banking sector's inadequate risk management strategies are failing to curtail inefficient NPLs, while a lack of robust macroeconomic policies exacerbates structural NPLs. To rectify this, there must be a concerted push towards overhauling banking risk management protocols and enhancing macroeconomic stability.

We argue that efforts to bolster credit-output efficiency should be laser-focused on the key sectors driving East Java's GRDP, particularly manufacturing, trade, and logistics. Furthermore, implementing macroprudential incentives for banks that effectively channel credit to these priority sectors while maintaining low levels of inefficient NPLs is crucial. This should be complemented by aggressive fiscal policies aimed at infrastructure development, which can serve as a backbone for sustainable economic growth. By identifying the origins of NPLs and enacting targeted policy measures, the banking sector in East Java can enhance credit-output efficiency, thereby fostering a more robust and inclusive economic landscape.

Competing Interests

The author(s) declare that there are no competing interests relevant to the content of this article.

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