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THE IMPACT OF FINANCIAL DEVELOPMENT ON THE CIRCULAR ECONOMY: THE ROLE OF INSTITUTIONAL QUALITY

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ABSTRACT

The linear economic model has revealed important limitations under growing pressures from resource depletion, emissions, and waste generation. The transition toward a circular economy (CE) requires substantial financial resources. However, financial development (FD) does not automatically improve circular-economy performance when capital allocation and institutional conditions are inadequate. This dissertation develops a national-level composite Circular Economy Index (CEI), examines the relationship between FD and the CE, and investigates the moderating role of institutional quality (IQ). It also compares these relationships between developed and developing countries. The study uses panel data for 109 countries over the 2002–2024 period. Principal Component Analysis (PCA) is employed to construct the CEI from four dimensions, while Bayesian regression and interaction terms are used to examine the relationship between FD and CE performance and the moderating role of IQ. Sensitivity analyses, robustness checks, and endogeneity tests are also conducted. The first principal component (PC1) explains 57.87% of the total variance. The average CEI is 0.864 for developed countries and 0.413 for developing countries. FD shows a positive and stable association with CE performance in developed countries, whereas the relationship is smaller and less stable in developing countries. Overall, stronger institutional quality improves this relationship.

The dissertation concludes that the contribution of FD to the CE depends on both capital allocation and institutional conditions. Developing countries should pay particular attention to credit allocation, the rule of law, regulatory quality, and transparency. The findings provide useful evidence for policymakers and other stakeholders involved in promoting the transition toward a circular economy.

Keywords: Circular economy; financial development; institutional quality; PCA; Bayesian regression.

CHAPTER 1: INTRODUCTION

1.1. Rationale for the Study

In recent decades, climate change, resource depletion, and increasing waste generation have exposed the limitations of the linear economic model based on the sequence of "extraction–production–consumption–disposal." Although this model can generate economic value in the short term, it also increases the extraction of virgin resources, emissions, and the amount of waste requiring treatment. According to Circle Economy (2024), the global economy consumes more than 100 billion tons of materials annually, yet only about 6.9% is cycled back into production processes. This indicates a substantial gap between the objectives and actual progress of the circular economy (CE). The transition toward the CE has also been uneven across countries. In the European Union, the municipal waste recycling rate reached approximately 48% in 2023, with Germany recording about 69%, whereas countries such as Cyprus, Greece, Bulgaria, and Romania reported rates of only around 12.8%–17.4%. These differences suggest that the ability to move toward a circular economy depends considerably on each country's economic, technological, financial, and institutional conditions.

One of the main barriers to the CE transition is the need for investment capital. Many circular projects involve high initial costs, long payback periods, considerable technological risks, and substantial market uncertainty. Therefore, beyond the ability to mobilize finance, the direction in which financial resources are allocated is equally important. Finance can support the CE only when it is directed toward clean technologies, renewable energy, recycling infrastructure, and activities that improve resource efficiency. At present, however, investment specifically dedicated to circular-economy activities remains limited, while specialized financial instruments have not developed at a comparable pace. In the finance and growth literature, financial development (FD) is associated with the capacity to mobilize

savings, allocate capital, screen projects, manage risks, and promote technological innovation. In the context of the CE, a developed financial system may help firms obtain the funding required for technological upgrading and improvements in resource efficiency. However, the relationship between FD and the CE is not necessarily positive in all circumstances. If credit is mainly directed toward resource-intensive and high-emission industries, financial expansion may increase material production and consumption. Chen et al. (2026), for example, find that credit to the private sector is positively associated with per capita municipal waste generation in 28 European countries.

Institutional quality (IQ) can shape the relationship between FD and the CE. Strong institutions reduce uncertainty, improve transparency, and support more efficient resource allocation (North, 1990; Acemoglu et al., 2005). Clear regulations, effective monitoring, and appropriate environmental policies may therefore help direct financial resources toward circular activities and strengthen the contribution of FD to environmental outcomes.

From an academic perspective, the CE is multidimensional, covering resource use, energy, emissions, and material recovery. Individual indicators capture only specific aspects, highlighting the need for a composite national-level CE measure. Examining this measure alongside institutional quality also enables comparison between developed and developing countries and helps identify the conditions under which financial development can better support circular-economy outcomes.

1.2. Research Objectives

The overall objective of the dissertation is to construct a composite Circular Economy Index at the national level that allows international comparison. Based on this index, the dissertation examines the relationship between financial development and the circular economy and clarifies the

moderating role of institutional quality. The study also analyzes differences between developed and developing countries and derives policy implications for supporting the circular-economy transition toward sustainable development.

To achieve this overall objective, the dissertation focuses on two specific objectives:

(i) to construct a composite Circular Economy Index that enables international comparison and to examine differences in the level and trend of circular-economy performance between developed and developing countries; and

(ii) to analyze the relationship between financial development and the circular economy, clarify the moderating role of institutional quality, and compare this relationship between developed and developing countries.

1.3. Research Questions

Based on these objectives, the dissertation addresses two main research questions.

First, how can an internationally comparable Circular Economy Index be constructed, and how do the level and trajectory of circular-economy performance differ between developed and developing countries?

Second, how is financial development associated with the circular economy, how does institutional quality moderate this relationship, and do these relationships differ between developed and developing countries?

1.4. Research Subject and Scope

The main research subject is the relationship between financial development and the circular economy and the moderating role of institutional quality in this relationship. The dissertation also examines the measurement of the circular economy at the macro level and differences in circular-economy performance between developed and developing countries. In terms of geographical scope, the study covers 109 countries,

including 30 developed and 79 developing countries. In terms of time, the dissertation uses panel data for the 2002–2024 period to ensure continuity and comparability across countries.

1.5. Research Methods

The dissertation combines a literature review with quantitative methods. PCA is used to construct a composite CEI based on four dimensions: carbon efficiency, energy efficiency, energy transition, and material pressure. Descriptive statistics and comparative tests are employed to assess the level, trend, and differences between developed and developing countries. Bayesian regression with interaction terms between FD and the dimensions of IQ is used to examine their relationships and the moderating role of institutions. Separate models are estimated for developed and developing countries. Sensitivity analyses and robustness checks are also performed to assess the stability of the results.

1.6. Contributions of the Dissertation

The dissertation makes theoretical, methodological, empirical, and practical contributions. Theoretically, it clarifies the moderating role of institutional quality in the relationship between financial development and the circular economy across developed and developing countries. Methodologically, it constructs a composite CEI using PCA and applies Bayesian regression to examine this relationship. Empirically, it provides evidence from 109 countries over 2002–2024. Practically, the findings inform financial and institutional policies aimed at improving capital allocation and supporting the circular-economy transition.

CHAPTER 2: THEORETICAL FRAMEWORK AND LITERATURE REVIEW

The circular economy (CE) provides an alternative framework to the linear "extract–produce–dispose" model. It aims to retain the value of products, materials, and resources within the economic system for as long as possible, thereby reducing the extraction of virgin resources and waste generation. From a value-retention hierarchy perspective, shorter loops such as repair and reuse generally preserve more value than recycling.

From a systems perspective, the CE extends beyond individual products. It involves business models, public policy, finance, and behavior and operates at the micro, meso, and macro levels.

The CE can also be understood as a process of economic restructuring aimed at reducing environmental pressures, preserving value, and limiting dependence on finite resources. This process seeks to slow, narrow, and close material loops while maintaining economic activity within ecological limits. Improvements in technical efficiency, however, do not automatically ensure sustainability if the overall scale of production and consumption continues to increase, because rebound effects may arise.

Based on this perspective, the dissertation approaches the CE at the macro level through four dimensions. Carbon efficiency reflects the ability to generate economic value with lower emissions. Energy efficiency captures the ability to generate greater economic value with lower energy use. Energy transition reflects the shift from fossil fuels toward renewable and low-emission energy sources. Material pressure captures the extent to which an economy depends on material resources in generating economic value.

Regarding financial development (FD), Levine (1997, 2005), Demirgüç-Kunt and Levine (2001), and Rajan and Zingales (1998) emphasize its functions in mobilizing savings, allocating capital, monitoring firms, managing risks, and reducing the cost of capital. Contemporary

approaches commonly consider FD through four dimensions: depth, access, efficiency, and stability. In this dissertation, FD is examined from the perspective of financial-intermediation depth and is measured by domestic credit to the private sector as a percentage of GDP because this indicator reflects the financial system's capacity to provide capital for investment, technological innovation, and production restructuring.

In the context of the CE, the financial system may direct capital toward clean technologies, renewable energy, and more resource-efficient activities. At the same time, financial expansion may reinforce resource-intensive production patterns when capital is not allocated appropriately. Institutional quality therefore plays an important role in reducing uncertainty, protecting property rights, improving monitoring effectiveness, and directing financial resources toward green and circular-economy objectives.

CHAPTER 3: RESEARCH MODEL AND METHODOLOGY

3.1. Construction of the Circular Economy Index

Based on the systems perspective presented in Chapter 2, the CE is not limited to recycling or waste treatment. It also concerns the way in which an entire economy extracts resources, uses energy, organizes production, and reduces environmental impacts. Accordingly, the dissertation constructs a macro-level CEI from four complementary indicators: material pressure (RE), energy transition (ET), carbon efficiency (CAE), and energy efficiency (EE). Circularity within the index is first reflected in the objective of generating economic value with lower resource use while reducing energy consumption and emission pressures.

First, material pressure (RE) reflects the quantity of material resources required to generate one unit of GDP. Among the four indicators, this measure is most directly related to the CE objective of reducing resource use.

Second, energy transition (ET) captures the share of renewable energy in the economy's energy structure. Circular activities such as collection, transportation, sorting, recycling, and remanufacturing all require energy. If these activities continue to depend heavily on fossil fuels, the recovery and reuse of materials may still generate substantial emissions.

Third, energy efficiency (EE) reflects the economic value generated per unit of energy consumed. One objective of the CE is to reduce the amount of resources required to sustain production and consumption. Higher EE means that an economy can generate more economic value from the same amount of energy input.

Fourth, carbon efficiency (CAE) reflects the economic value generated relative to carbon emissions. The transition toward a CE seeks to reduce environmental impacts throughout resource extraction, production, use, and end-of-life treatment. Higher carbon efficiency therefore indicates that an economy generates more value relative to its emissions.

The carbon intensity of GDP (CAE) is used to represent carbon efficiency because it measures the amount of emissions associated with one unit of economic value. Lower carbon intensity indicates that an economy depends less on high-emission production and carbon-intensive technologies. CAE is therefore treated as an inverse indicator in accordance with the CE objective of reducing environmental impacts.

GDP per unit of energy use (EE) is selected to measure energy efficiency because it reflects the economy's capacity to generate value from each unit of energy input. Higher EE indicates more efficient energy use and greater progress toward decoupling economic growth from energy consumption.

The share of renewable energy in total primary energy consumption (ET) is included to capture the energy transition. This indicator reflects not only current energy-use performance but also the economy's longer-term capacity to restructure its energy system away from fossil fuels.

Domestic material consumption relative to GDP (RE) is used to measure material pressure because it reflects the extent to which economic activity depends on material inputs. Higher RE indicates that economic growth remains strongly dependent on resource extraction and consumption, whereas lower RE indicates the ability to generate GDP with fewer material inputs.

3.2. Research Model for the Relationship Between Financial Development and the Circular Economy: The Role of Institutional Quality

The dissertation treats FD as a mechanism through which capital is mobilized and allocated between circular and linear activities rather than assuming that financial development automatically improves CE performance. This argument integrates financial intermediation theory,

sustainability signaling theory, sustainable-development disruption arguments, institutional theory, and resource-efficiency perspectives.

Total investment in a country in a given year can be considered as comprising investment in circular activities and investment in linear activities. The share of capital allocated to circular activities represents the link between FD and the CE. According to financial intermediation theory, a more developed financial system can mobilize funds, reduce information asymmetry, screen projects, and manage risks more effectively. However, financial flows toward circular activities may be disrupted when projects involve high initial costs, long payback periods, substantial technological risks, or uncertain economic returns. Under such conditions, capital may return to conventional industries where short-term profitability is clearer.

In the theoretical framework, FD represents financial development, IQ represents institutional quality, and their interaction captures the moderating role of institutions. At the macro level, CE performance reflects the ability of an economy to generate economic value with lower emissions, energy consumption, and material pressure while increasing the use of renewable energy. The model also incorporates a set of control variables representing macroeconomic conditions that may influence CE performance. Combining these relationships yields the general theoretical model used in the dissertation.

3.3. Data and Sample Size

The screening process began with 195 countries and economies. Fifteen observations representing aggregate groups or territories outside the scope of the study were excluded, leaving 180 countries. After country codes were matched across data sources, 21 countries that did not meet data-linkage requirements were excluded, leaving 159 countries for further screening. The study applied a 10% missing-data threshold. Countries were considered for exclusion when missing observations exceeded 10%,

persisted for long periods, or affected most of the time series for a core variable. The proportion of missing data ranged from 0.40% to 8.02%, remaining below the specified threshold. The remaining missing observations were therefore considered manageable. The stability analysis comparing the data before and after imputation, reported in Appendix 6, shows that the mean values of the variables changed very little. The differences between the pre-imputation and post-imputation means ranged from 0.41% to 0.65%. RL recorded the largest change at 0.65%, whereas CAE and ET recorded the smallest changes at 0.41%. For PS, the mean declined by 0.55%, although the magnitude of the change remained very small.

3.4. Research Methods

PCA is used to construct the CEI. The correlation matrix of the indicators is first examined to assess relationships among the variables. PCA is then used to reduce the information contained in the original indicators into principal components, with the first component explaining the largest proportion of total variance. Component loadings are used to determine the relative contribution of each indicator and to construct the composite CEI. The dissertation then employs Bayesian regression to examine the relationship between financial development and CE performance and the moderating role of institutional quality. Bayesian estimation derives posterior distributions of model parameters by combining prior information with observed data. The relationships are evaluated using posterior means, posterior intervals, and posterior probabilities concerning the direction of the coefficients. Interaction terms between FD and each dimension of institutional quality are included to examine moderation. Separate models are estimated for developed and developing countries. MCMC convergence diagnostics, prior sensitivity analyses, and robustness checks are also conducted to assess the reliability and stability of the results.

CHAPTER 4: EMPIRICAL RESULTS

4.1. Principal Component Analysis Results

Before conducting PCA, the study examines four indicators: the carbon intensity of GDP (CAE), energy efficiency (EE), energy transition (ET), and material pressure (RE). The indicators display substantial variation across countries, providing sufficient variation for identifying a common underlying structure. The diagnostic results indicate that the data are suitable for PCA. The Kaiser–Meyer–Olkin measure is 0.7620, and Bartlett's test of sphericity is statistically significant at the 1% level.

PCA is performed using the full sample to ensure that the same weights are applied to both groups of countries. PC1 has an eigenvalue of 2.3149 and explains 57.87% of the total variance. It is the only component with an eigenvalue above 1 and is therefore retained under the Kaiser criterion. The scree plot also supports the retention of PC1. After CAE and RE are reverse-coded, all indicators have positive loadings on PC1. ET and EE have the highest loadings, at 0.5939 and 0.5919, respectively, indicating that the two energy-related dimensions make particularly strong contributions to the common CE structure.

The CEI is then constructed from the component loadings and normalized to a range of 0 to 1 using Min–Max normalization, with higher values indicating relatively stronger circular-economy performance.

4.2. Differences in Circular-Economy Performance Between the Two Country Groups

The heat map of the CEI for 109 countries over the 2002–2024 period reveals clear differences across countries and over time. The index is normalized from 0 to 1, with higher values representing stronger CE performance. Countries with high CEI values are primarily developed economies, including Sweden, Denmark, Norway, the United Kingdom, Switzerland, the Netherlands, Finland, France, and Germany. The middle-

performing group includes both developed and developing economies, such as Spain, Italy, China, Poland, Chile, Brazil, and Malaysia. Based on the CEI, the dissertation further examines differences between developed and developing countries using Levene's test, Welch's t-test, and the Mann–Whitney U test. Levene's test yields a statistic of 20.551 with $p < 0.001$, rejecting the assumption of equal variances between the two groups. Welch's t-test is therefore employed and produces $t = -14.111$ with $p < 0.001$. The mean CEI for developed countries is 0.864, significantly higher than the value of 0.413 for developing countries. This result indicates a substantial gap in circular-economy performance between the two groups. The Mann–Whitney U test produces $U = 67$ with $p < 0.001$, confirming that the difference remains statistically significant without imposing a normality assumption.

4.3. Bayesian Regression Results

The mean CEI for the full sample is 0.537. Developed countries have a mean CEI of 0.864, substantially higher than the 0.413 recorded for developing countries. The highest value is observed for Sweden in 2024 at 1.000, whereas Madagascar records the lowest value in 2024 at 0.000. This gap reflects substantial differences in technology, infrastructure, governance capacity, and resource-use efficiency.

The mean level of FD for the full sample is 58.553% of GDP, with a standard deviation of 45.151, indicating substantial variation in financial depth. Developed countries record a mean of 105.062%, considerably higher than the 40.891% observed in developing countries. This difference reflects the generally greater capacity of developed economies to mobilize and allocate financial resources.

For institutional quality, all six indicators—CC, GE, PS, RL, RQ, and VA—have substantially higher mean values among developed countries. Developing countries record negative average values for all six dimensions.

High values are commonly observed in Finland, Luxembourg, and Norway, whereas low values occur in Nigeria, Haiti, Pakistan, Zimbabwe, and Myanmar. These results indicate that institutional quality represents a fundamental difference between the two groups and support the examination of its moderating role.

The control variables also differ considerably between the two groups. Average GDP per capita growth in developing countries is 2.644%, compared with 1.566% in developed countries. This reflects a catch-up pattern but does not necessarily imply higher CE performance.

Average FDI is 6.160% of GDP for the full sample. Developed countries record an average of 12.616%, compared with 3.708% for developing countries, together with substantial variation.

Average urbanization for the full sample is 61.438%. The corresponding value is 78.027% for developed countries and 55.139% for developing countries.

Average inflation is 6.295%, but it is considerably higher in developing countries at 7.800% than in developed countries at 2.331%, indicating greater macroeconomic instability.

Unemployment rates are relatively similar across the two groups, at 7.227% and 7.370%, respectively, although developing countries display greater dispersion.

4.3.4. Bayesian Regression Results

4.3.4.1. Moderating Role of Control of Corruption (CC)

For developed countries, FD shows a clear positive relationship with CE performance. The posterior coefficient of FD is 0.0021 in the model without the interaction term and 0.0023 after FD × CC is introduced. The posterior probability that the coefficient is positive is 1.0000 in both models.

This indicates that a more developed financial system is associated with greater support for investment in clean technologies, renewable energy, and circular activities.

Control of Corruption (CC) is also positively associated with CE performance. The CC coefficient decreases from 0.0608 to 0.0226 after the interaction term is introduced, while the posterior probabilities of a positive coefficient remain high at 1.0000 and 0.9762, respectively.

Notably, FD × CC has a coefficient of 0.0009 and a posterior probability of a positive coefficient of 1.0000. This result indicates that stronger control of corruption strengthens the positive relationship between FD and the CE in developed countries.

For developing countries, FD does not show a clear positive direct relationship with CE performance. The posterior coefficient is approximately −0.0001 in both models, with posterior probabilities of a negative coefficient of 0.7949 and 0.6798, respectively.

This suggests that financial expansion alone may be insufficient to improve CE performance when capital is not effectively directed toward clean technologies, renewable energy, and circular infrastructure.

In contrast, CC has a clear positive relationship with CE performance, with coefficients of 0.0775 and 0.0650 and posterior probabilities of a positive coefficient of 1.0000 in both models.

4.3.4.2. Moderating Role of Government Effectiveness (GE)

Overall, Government Effectiveness has a positive direct relationship with CE performance in both groups, while its moderating role is more evident among developed countries.

For developing countries, improvements in government effectiveness remain an important institutional condition for directing financial resources toward activities that support the circular economy.

4.3.4.3. Moderating Role of Political Stability (PS)

For developed countries, FD is positively and consistently associated with CE performance, with coefficients of 0.0023 and 0.0026 and posterior probabilities close to 1. PS is also positive, while the interaction term FD × PS (0.0008; $P(\beta > 0) = 1.0000$) indicates that greater political stability strengthens the positive FD–CE relationship. GDP and INT generally have positive coefficients, whereas FDI and INF tend to be negative. For developing countries, FD has negative direct coefficients (−0.0005 and −0.0007), while PS remains positively associated with CE performance. The positive FD × PS coefficient (0.0002; $P(\beta > 0) = 0.9978$) suggests that political stability improves the relationship between FD and the CE. Among the controls, GDP, FDI, INF, and UNE are generally negative, whereas UR shows a small positive coefficient.

4.3.4.4. Moderating Role of the Rule of Law (RL)

For developed countries, FD is positively and consistently associated with CE performance, while RL also shows a strong positive relationship. The interaction term FD × RL is positive (0.0008; $P(\beta > 0) = 1.0000$), indicating that stronger rule of law reinforces the positive relationship between FD and the CE. In developing countries, the direct FD effect is weaker and becomes negative in the interaction model (−0.0007; $P(\beta < 0) = 0.9897$), whereas RL remains strongly positive. The positive FD × RL coefficient (0.0006; $P(\beta > 0) = 0.9961$) confirms a clear moderating role of rule of law in both groups.

A similar pattern is observed for regulatory quality. In developed countries, FD remains positive and stable, while RQ is strongly positively associated with CE performance. The FD × RQ coefficient is 0.0009 with $P(\beta > 0) = 1.0000$, indicating that better regulatory quality strengthens the FD–CE relationship. In developing countries, the direct FD coefficient becomes negative after the interaction is introduced (−0.0005; $P(\beta < 0) =$

0.9299), whereas RQ remains strongly positive, suggesting that regulatory quality is an important institutional condition for improving the contribution of financial development to CE performance.

4.3.4.6. Moderating Role of Voice and Accountability (VA)

4.3.4.7. Model Convergence Diagnostics

The convergence diagnostics include the R-hat statistic, effective sample size (ESS), and Monte Carlo standard error (MCSE), with detailed results reported in the Appendix. R-hat values below 1.01 indicate that the MCMC chains converged toward the same posterior distribution. Bulk ESS and Tail ESS are used to assess the effective number of posterior draws in the central and tail regions of the posterior distribution. An ESS above 400 is treated as a practical threshold for ensuring sufficient precision in posterior estimates.

4.3.5. Robustness and Sensitivity Analyses

4.3.5.1. Robustness Check Using Material Flow (MF) as an Alternative Dependent Variable

MF is used as an alternative dependent variable because it directly reflects material pressure in the economy and is relevant to the assessment of the CE transition. Because MF moves in the opposite direction to the CEI, a positive coefficient in the CE model corresponds conceptually to a negative coefficient in the MF model. For the 30 developed countries, FD has a negative coefficient in all six models, with $P(\beta < 0)$ ranging from 0.976 to 0.998. The FD × IQ interaction terms are also negative, with posterior probabilities ranging from 0.982 to 1.000. For the 79 developing countries, both FD and the interaction terms have negative coefficients, with posterior probabilities above 0.968. Overall, these results indicate that FD is associated with lower MF and that stronger institutional quality reinforces the relationship between FD and reduced material pressure. The findings therefore support the robustness of the main results.

4.3.5.2. Robustness Checks by Lag Structure and Subperiod

The interaction coefficients between FD and IQ generally remain positive across all six institutional dimensions. For the 30 developed countries, the moderating relationships remain stable and are often stronger when shock periods are excluded, particularly for Political Stability, Rule of Law, and Control of Corruption. For the 79 developing countries, the positive signs are also maintained, although the coefficients are smaller and more variable. Government Effectiveness shows the weakest moderating relationship, whereas Political Stability, Rule of Law, Regulatory Quality, and Voice and Accountability display greater stability.

4.3.5.3. Prior Sensitivity Analysis

The dissertation next examines the sensitivity of the results to alternative prior specifications. The objective is to determine whether the conclusions regarding the moderating role of institutional quality depend on the choice of prior distributions.

The baseline models use regularizing priors. These priors moderately concentrate the coefficients around zero, thereby limiting extreme estimates and overfitting while still allowing the observed data to play the main role in shaping the posterior distributions.

To assess sensitivity, the models are re-estimated using two alternative prior specifications.

4.3.6. Endogeneity Tests

Endogeneity may arise when an explanatory variable is correlated with the model error term, potentially producing biased and inconsistent coefficient estimates. To assess whether FD is affected by this problem, the study applies the Durbin–Wu–Hausman (DWH) endogeneity test. The DWH procedure is widely used to assess whether a potentially endogenous explanatory variable can reasonably be treated as exogenous by comparing estimates obtained under different assumptions regarding the relationship

between the explanatory variable and the error term. The results provide no statistically significant evidence of endogeneity in FD for either group. For developed countries, the Durbin score test produces $\chi^2 = 1.84$ with $p = 0.175$, while the Wu–Hausman test gives $F = 1.79$ with $p = 0.182$. For developing countries, the corresponding results are $\chi^2 = 2.06$ with $p = 0.151$ and $F = 1.97$ with $p = 0.161$.

Because all p-values exceed conventional significance levels, the null hypothesis is not rejected for either country group. To provide additional evidence within a framework consistent with the main estimation approach, the study also employs a Bayesian instrumental-variable model, using private-sector credit lagged by two years as the instrumental variable. In this model, the correlation coefficient of the error terms, ρ, between the FD equation and the CE equation is used to assess potential endogeneity. The posterior mean of ρ is 0.0852 for developed countries and −0.0439 for developing countries. The corresponding 95% credible intervals are [−0.0251, 0.1921] and [−0.1073, 0.0196], both of which include zero.

4.3.7. Test for Omitted-Variable Bias

Omitted-variable bias may arise when unobserved factors are correlated with both financial development and CE performance, potentially biasing the estimated coefficient of FD. To assess the sensitivity of the results to this risk, the dissertation applies the coefficient-stability method proposed by Oster (2019).

The Oster (2019) method compares the coefficient of FD and model fit between a restricted specification and a specification containing a fuller set of control variables. This comparison is used to calculate an adjusted coefficient and the parameter δ. The δ parameter indicates how strong selection on unobservables would need to be, relative to selection on observed variables, to reduce the estimated FD coefficient to zero. An absolute δ value greater than 1 is commonly interpreted as evidence that the

result is relatively robust to omitted-variable bias. The FD coefficient remains positive after additional control variables are introduced for both country groups. For developed countries, the FD coefficient declines from 0.0028 in the restricted model to 0.0021 in the full model, while R^2 increases from 0.412 to 0.568. With Rmax = 0.738, the bias-adjusted coefficient remains positive at 0.0017. In addition, $\delta = 2.36$, indicating that selection on unobserved factors would need to be approximately 2.36 times as strong as selection on the observed variables to reduce the estimated relationship between FD and the CE to zero.

For developing countries, the FD coefficient declines from 0.0019 to 0.0014 between the restricted and full specifications, while R^2 increases from 0.365 to 0.497.

With Rmax = 0.646, the adjusted coefficient remains positive at 0.0011 and δ equals 1.74.

Thus, δ exceeds 1 in both groups and the adjusted coefficients retain their positive signs. These results indicate that the estimated relationship between FD and the CE is relatively robust to potential omitted-variable bias.

4.3.8. Bayesian Granger Causality Test from the Circular Economy to Financial Development

Two hypotheses are evaluated using the Bayes factor (BF_{10}), which measures the relative evidence provided by the data for the unrestricted model compared with the restricted model. Specifically, BF_{10} is calculated as the marginal likelihood of the data under the unrestricted model divided by that under the restricted model. The unrestricted model includes the one-year lag of CE performance, whereas the restricted model does not. A BF_{10} value greater than 1 indicates greater support for the unrestricted model, whereas a value below 1 indicates greater support for the restricted model. The estimated BF_{10} values are 0.18 for developed countries and 0.24 for

developing countries, both below 1. Accordingly, the results do not provide evidence of Granger causality from the CE to FD in either country group.

4.4. Discussion of the Findings

The Bayesian regression results provide consistent support for hypothesis H1a for the 30 developed countries.

The FD coefficient is positive in all six models using different dimensions of institutional quality. Posterior means range from 0.0017 to 0.0026, and the posterior probability of a positive coefficient is at least 0.9999. This indicates that domestic credit to the private sector is positively associated with CE performance among developed countries. In the interaction models, a one-percentage-point increase in FD, holding other factors constant, is associated with an increase of approximately 0.0017–0.0026 units in the CEI at the reference level of the institutional variable. These findings are consistent with H1a and can be interpreted through financial intermediation theory and sustainability signaling theory. Financial intermediation theory emphasizes the role of the financial system in mobilizing funds, selecting projects, allocating resources, and managing risks. In the CE context, these functions may facilitate firms' access to long-term finance for technological innovation, energy saving, material reuse, and process improvement. Sustainability signaling theory, meanwhile, emphasizes the role of information and sustainability commitments in shaping investment decisions.

For the 79 developing countries, hypothesis H1b does not receive consistent support. In models without interaction terms, the FD coefficient is negative in the CC model (−0.0001; $P(\beta < 0) = 0.7949$) and the PS model (−0.0005; $P(\beta < 0) = 1.0000$), but positive and very small in the GE, RL, RQ, and VA models. The posterior probability of a positive coefficient in these four models ranges from 0.6998 to 0.9066. After the interaction terms are introduced, the standalone FD coefficient in all six models becomes negative

or close to zero, with posterior probabilities of a negative coefficient ranging from 0.5622 to 0.9897. In summary, H1a is consistently supported, whereas H1b is not consistently supported. The results for developed countries are consistent with the arguments of financial intermediation theory and sustainability signaling theory: the capacity to mobilize finance, together with reliable information, may facilitate circular-economy activities.

For developing countries, however, the findings suggest that greater financial resources do not necessarily translate into positive changes in the way resources are used. An empirical contribution of the dissertation is its assessment of the relationship between FD and the CE using a common composite indicator for 30 developed and 79 developing countries over the 2002–2024 period. Unlike studies that rely on firm-level data or individual indicators such as CO_2 emissions, recycling rates, or municipal waste, this dissertation integrates four carbon-, energy-, and material-related dimensions within a single CE measure. The findings indicate that credit expansion is positively and consistently associated with CE performance in developed countries, whereas this relationship is considerably less stable in developing countries.

For the 30 developed countries, each individual dimension of institutional quality is positively associated with the CE. For example, in the models without interaction terms, the posterior means are 0.0608 for Control of Corruption, 0.0944 for Government Effectiveness, 0.0187 for Political Stability, 0.0888 for Rule of Law, 0.1071 for Regulatory Quality, and 0.0661 for Voice and Accountability. These findings are consistent with the argument that better governance can provide a more supportive environment for environmental-policy implementation, infrastructure organization, and more efficient resource use.

CHAPTER 5: CONCLUSIONS AND POLICY IMPLICATIONS

5.1. Conclusions

The first main result of the dissertation is the construction of a macro-level Circular Economy Index based on four dimensions: carbon efficiency, energy efficiency, energy transition, and material pressure. The diagnostic tests confirm that the data are suitable for PCA. The KMO measure is 0.7620, while the first principal component has an eigenvalue of 2.3149 and explains 57.87% of the total variance. Energy transition and energy efficiency make particularly strong contributions to the first principal component, while carbon efficiency and material pressure remain necessary for preserving the multidimensional nature of the index. After Min–Max normalization to the 0–1 range, the CEI allows comparison across countries and over time. Developed countries have an average CEI of 0.864, significantly higher than that of developing countries. The two groups also differ in the dispersion and trajectories of their CE performance. The second main result is that the relationship between financial development and the circular economy differs substantially depending on the level of economic development. For the 30 developed countries, FD has a positive and stable relationship with CE performance across the Bayesian models, including those incorporating different dimensions of institutional quality. For the 79 developing countries, the direct FD coefficient is smaller, less stable, and negative in some specifications. These findings indicate that an expansion of credit or greater financial depth does not automatically translate into improved CE performance when capital allocation and institutional conditions remain inadequate.

5.2. Policy Implications

First, policymakers should shift attention from simply expanding the volume of credit toward improving the quality of capital allocation.

Because the relationship between financial development and CE performance differs across country groups and depends on institutional conditions, financial authorities may consider integrating circular-economy criteria into credit assessment, risk management, and capital-allocation frameworks. Second, stronger coordination is needed between financial policy and policies relating to industry, energy, taxation, innovation, public procurement, and waste management. Such coordination can help reduce policy inconsistencies in which financial incentives support the CE while other policies continue to encourage fossil-fuel use or intensive resource extraction. For developed countries, the main priority is no longer simply to deepen the financial system but to improve the circularity of capital portfolios. Transparency and the control of greenwashing should also be strengthened through life-cycle data, clear standards, and independent monitoring mechanisms. Institutional reform should proceed alongside financial development, particularly in areas such as the rule of law, regulatory quality, policy stability, and accountability. Investment in data infrastructure is also important. This includes material-flow statistics, waste registries, material-tracing systems, and emissions databases that can support monitoring and guide the allocation of financial resources. For Vietnam, the broader findings suggest the value of providing clearer credit orientation toward circular activities, incorporating resource-efficiency criteria into project appraisal, developing lending products that better match the long-term cash-flow profiles of circular projects, and improving access to finance for small and medium-sized enterprises. These measures should be accompanied by stronger environmental-risk management, post-disbursement monitoring, and coordination among banks, firms, and other participants in the circular-economy ecosystem.

LIST OF THE AUTHOR'S PUBLICATIONS

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