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Carbon Tax Policy, Stranded Assets and "Double Pillar" Regulation

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Abstract

The risk of a transition from climate policy has drawn widespread attention from central banks. By constructing a new Keynes dynamic stochastic general equilibrium model (NK-DSGE) including climate policy, asset quality and "two-pillar" policy, this paper studies the possible transition risk caused by carbon tax policy and analyzes the transition risk from the perspective of stranded assets. On this basis, the effect of the "dual-pillar" policy to deal with the transformation risk is further evaluated and the optimal policy combination is found through the comparative analysis of social welfare. Research shows that:(1)carbon tax policy has a significant emission reduction effect, but it may cause "stagflation" and lead to the "grounding" of carbon-intensive assets, causing a certain risk of transformation.(2)When the central bank deals with the risk of transformation, it should not only focus on the inflation target. At the same time, we should actively stimulate output, promote the development of the low-carbon sector, solve the mismatch between energy supply and demand, and address the root cause of inflation. When the central bank operates the price monetary policy, the central bank can reduce the risk of transformation and improve the operation efficiency through interest rate smoothing.(3)The macro-prudential policy of "brown punishment" can effectively alleviate the risk of transformation and improve social welfare. The macro-prudential policy of "green support" will not only promote the economic recovery, but also lead to the rising leverage ratio of banks in the short term, aggravating the financial risks faced by banks and causing the loss of social welfare.(4)An effective "two-pillar" policy mix is better to the single use of monetary policy tools in mitigating transition risks and improving social welfare.

Keywords

Carbon Tax; Stranded Assets; Transition Risk; "Double Pillar"Policy.

1. Introduction

Since the 21st century, the physical risks and transformation risks brought about by climate change have seriously threatened the safety of human life and property. Countries around the world attach great importance to this issue and have signed a series of climate conventions to limit greenhouse gas emissions. While actively responding to climate issues, we should also pay attention to the risks of transition caused by climate policy. Central bank and regulators green financial network (NGFS) pointed out that climate policy may lead to part of the enterprise assets face value or even the risk of stranded, and through the price, investment and production channels threaten the macro economy, the risk caused by climate policy is called transformation risk, assets "stranded" is one of the important forms of transformation risk. Stranded assets are the assets with economic consequences such as economic income loss and asset depreciation due to the low-carbon economic transformation, which are mainly concentrated in carbon-intensive assets. The unexpected depreciation of these assets may

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trigger fire asset sales, exacerbate asset price fluctuations, threaten financial stability, and trigger economic systemic risks through the interaction between the entity and the finance. In recent years, how to effectively mitigate and control climate-related risks has become a major research topic of regulatory authorities.

2. Literature Review

Since the beginning of the 21st century, climate change has become an important challenge facing mankind. Countries around the world have signed a series of climate conventions to limit carbon emissions. By signing the Paris Agreement, countries have agreed to limit the increase in global average temperature within 2℃ from pre-industrial periods, and strive to limit it within 1.5℃. It is widely believed that the climate change problem essentially comes from market failure, that is, the negative externality of carbon emissions. People produce and consume carbon products without paying anything for their negative externalities. So companies and consumers have no direct incentive to reduce emissions. From the practice of various countries, carbon tax is the main climate governance tool to solve the negative externalities of carbon emissions. The negative externalities of carbon emissions into the carbon price, thus encouraging businesses and consumers to reduce carbon emissions.

According to the existing literature, the research on carbon tax mainly focuses on the macro economy and the emission reduction effect, while there is little research on finance. Fischer et al. (2011) found that the carbon tax policy will lead to macroeconomic fluctuations and cause a certain loss of social welfare. Lou Feng (2014) found that carbon tax may lead to greater upward price pressure, but the improvement of energy efficiency can effectively restrain the upward price pressure. At the same time, the carbon tax policy is heterogeneous in the output and price fluctuations of different industries. Wang Shuping (2016) found that the negative impact of carbon tax policy on output is short-term and is conducive to the improvement of environmental quality in the medium and long term. CAI Dongliang et al. (2019) found that the carbon tax is conducive to improving environmental quality and is not conducive to economic growth, but the mixed policy including carbon emission subsidy and carbon tax policy is conducive to both environmental improvement and economic growth. Cheng Na et al. (2021) found that carbon tax can effectively reduce carbon emission intensity, but it will have a negative impact on economic growth, but the inclusion of Marine carbon sink in the economic system can effectively reverse the negative effect of carbon tax on economic growth. Mohommad (2021) Research found that the carbon tax increases the marginal cost of high-carbon enterprises, leading to reduced labor demand and output of high-carbon enterprises.

With the gradual exposure of transformation risks, the research on carbon tax, transformation risk and regulatory measures is also gradually increasing. Among them, research on transformation risks and financial stability mostly focus on stranded assets. Spiganti et al. (2017) found that the grounding of carbon-intensive assets caused by the carbon tax policy may cause a "carbon bubble" in the capital market. On this basis, the effectiveness of different government measures to alleviate the "carbon bubble" is also discussed. Annicchiarico et al. (2020) found that carbon price is closely related to the formation of transition risk. Compared with the linear increased carbon price, the transformation risk caused by the exponentially increased carbon price is controllable. Green credit policies are effective in alleviating the risks of transformation, and improper macro-prudential policies may exacerbate financial risks. Benmir et al. (2020) studied the performance of macro-prudential regulation and credit easing policies in response to the impact of the optimal level of carbon tax. Wei Ping (2021) sorted out the transmission path of stranded assets caused by climate policies such as carbon tax. Diluiso et al. (2021) found that the pace of carbon tax collection is closely related to the formation of transformation risk. Compared with delaying the collection of carbon tax, the orderly transition cost of carbon tax is limited, and time and expectations play a key role in limiting the risk of transition. Green quantitative easing policy is effective in dealing with the risks of transformation, but it cannot be used as a separate green financial tool to promote the low-carbon transformation of the economy. Wang Bo et al. (2021) found that both fixed carbon prices and floating carbon prices have a certain negative impact in the short term, but they will contribute to the high-quality development of China's economy in the long term. Monetary policy combined with macro-prudential policies is conducive to alleviating the transformation risks caused by climate policy and improving the level of residents' welfare. Carattini et al. (2021) found that when there is financial friction in the system, the economy will face a greater risk of transformation. The combination of macro-prudential policies can effectively alleviate the transformation risks brought about by the carbon tax, but the performance of macro-prudential policies is not effective when dealing with environmental externalities as independent green financial instruments. Yan Yi (2023) found that punitive carbon tax policies will bring certain risks to commercial banks, but they can effectively alleviate economic contraction and prevent financial risks when combined with incentive emission reduction policies. Hu Xiaowen (2023) found that the policy combination of monetary policy and counter-cyclical capital supervision can effectively alleviate the systemic financial risks of banks caused by emission reduction policies. Chen Guojin et al. (2023) found that the combination of carbon taxes, green refinancing and macro-prudential policies is more conducive to achieving a stable and low-carbon economic transition.

A growing number of scholars believe that climate-related risks cannot be viewed in isolation, and that a holistic and systemic policy combination is needed. ECB President Lagarde (2020) stressed that climate-related risks should be included in the risk assessment model and discussed how monetary policy can respond to climate-related risks. From the regulatory practices of various countries and the existing literature, strengthening macro-prudential supervision can effectively alleviate the risks of transformation. Yi Gang, governor of the People's Bank of China (2021), said at a high-level seminar on "Green Finance and Climate Policy" that climate risks will gradually be included in the macro-prudential policy framework. After the financial crisis, it has become a common consensus of the international community to establish the dual pillar of "macro-prudential policy specifically focuses on the financial stability target and monetary policy mainly focuses on the economic stability target".

3. DSGE Model Building

In this paper, we construct an NK model that includes households, final goods production sector, retail sector, low-carbon energy production sector, fossil energy production sector, capital production sector, banks, and public sector. The specific model of this paper is set as follows:

3.1. Household Sector

Suppose that there are a large number of homogeneous families in the society, and that the existence of life is continuous. part of the family f is a banker who manages financial intermediaries,Another part $1-f$ is the worker who provides labor.Bankers with constant probability $1-\theta$ exit in the next issue,Each issue will have $(1-\theta)f$ of workers will randomly turn into bankers, keeping a fixed percentage of each occupation.

Consumption brings positive utility to households, and labor brings negative utility to households. Households maximize their utility within the constraints of wage income, capital gains, bond earnings, and government tax budgets.

$$\max_{C_t,N_t,B_t} E_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{(C_t-h_c C_{t-1})^{1-\zeta}-1}{1-\zeta} - \chi \frac{N_t^{1+\varphi}}{1+\varphi}\right] \quad (1)$$

$$s.t. \quad C_t = W_t N_t - T_t + D_t + R_t B_{t-1} - B_t \tag{2}$$

There into E is Expectation operator,$\beta$is the discount factor,$0 < \beta < 1$,$\zeta$is the intertemporal substitution elasticity of consumption,$\varphi$is Provide elasticity for labor,$h_c$is the coefficient of inertia of consumption,$\chi$is the degree of aversion of the inhabitants to the provision of labor.

The main source of income for a family is labor income $W_t N_t$,Government Taxes and TransfersT_t,Invest in the form of bank savings and bond purchasesB_t,the investment income obtained $R_t B_{t-1}$,Corporate dividends D_t .The first-order maximization conditions from the family are as follows:

$$(C_t - h_c C_{t-1})^{-\zeta} - \beta h_c E_t \mu_{t+1}^{\beta} (C_{t+1} - h_c C_t)^{-\zeta} = \lambda_t \tag{3}$$

$$\chi N_t^{\varphi} = \lambda_t W_t \tag{4}$$

$$\beta E_t \Lambda_{t,t+1} R_{t+1} = 1 \tag{5}$$

$$\Lambda_{t,t+1} = \frac{\lambda_{t+1}}{\lambda_t} \tag{6}$$

Equation 3 represents the marginal utility of consumption by representative households, Equation 4 represents the supply of labor provided by households to various sectors, Equation 5 represents the first-order conditions of sectoral bonds held by households, and Equation 6 represents the random discount factor of representative households.

3.2. Production Department

The Retail segment is primarily responsible for producing the final product into the final product produced by the departmentY_tPackaged and sold, the packaged functions are:

$$Y_t = \left(\int_0^1 Y_{k,t}^{(\sigma_t - 1)/\sigma_t} \, dk \right)^{\sigma_t/(\sigma_t - 1)} \tag{7}$$

Thereinto, $k \in [0,1]$, $Y_{K,t}$ Indicates the firstkfinal products produced by the final product production department,σ_tIndicates the substitution elasticity of the final product. Suppose the price of the retail product is p_t, The final product price is $p_{k,t}$, The retail sector maximizes its profit function:

$$\max_{Y_{k,t}} P_t Y_t - \int_0^1 P_{k,t} \, Y_{k,t} dk \tag{8}$$

Solve the first-order condition to obtain the demand function of the final product:

$$Y_{k,t} = \left(\frac{P_{k,t}}{P_t} \right)^{-\sigma} Y_t \tag{9}$$

The retail sector is a perfectly competitive market, and according to the classical assumption that the profit of perfectly competitive firms is zero, the formula for calculating the nominal gross output by equation (9) is as follows:

$$P_t Y_t = \int_0^1 P_{k,t} Y_{k,t}\, dk \tag{10}$$

Substituting the final goods demand function into the equation of the total price level index can be obtained:

$$P_t = \left(\int_0^1 \left(P_{k,t}\right)^{1-\sigma_t} \right)^{1/1-\sigma_t} \tag{11}$$

The final product production sector is made through wage labor$N_{Y,t}$and lease capital$K_{Y,t}$to produce intermediate goods $VA_{Y,k,t}$, Intermediate products are then used $VA_{Y,k,t}$ and energy $E_{k,t}$ Production of the final product, Among them, energy includes low-carbon energy$E_{L,k,t}$and fossil fuels$E_{F,k,t}$.The final product production function is:

$$Y_{k,t} = \left[\varpi_{VA_Y}^{1/\varepsilon_Y} VA_{Y,k,t}^{(\varepsilon_Y-1)/\varepsilon_Y} + \varpi_E^{1/\varepsilon_Y} E_{k,t}^{(\varepsilon_Y-1)/\varepsilon_Y} \right]^{\varepsilon_Y/(\varepsilon_Y-1)} \tag{12}$$

Thereinto, ϖ_{VA_Y} andϖ_E is the corresponding weight of the two combined elements in the production input.$\varepsilon_Y > 0$is the substitution elasticity of the two combination elements during the period,hypothesis $\varepsilon_Y \in (0,1)$, that is, the complementarity of the two combination elements to a certain extent. The total energy input function is:

$$E_{k,t} = \left[\varpi_{E_L}^{1/\varepsilon_E} E_{L,k,t}^{(\varepsilon_E-1)/\varepsilon_E} + \varpi_{E_F}^{1/\varepsilon_E} E_{F,k,t}^{(\varepsilon_E-1)/\varepsilon_E} \right]^{\varepsilon_E/(\varepsilon_E-1)} \tag{13}$$

Assume alternative elasticity between low-carbon energy and fossil energy$\varepsilon_E > 1$, It means that the two energy sources are not completely substitutable in the input.$\varpi_{E_L}$and$\varpi_{E_F}$is the corresponding weight of the two energy sources in the production inputs.Intermediates$VA_{Y,k,t}$the production function is:

$$VA_{Y,k,t} = A_{Y,t} \left(\xi_{Y,t} K_{Y,k,t} \right)^{\alpha_Y} N_{k,t}^{1-\alpha_Y} \tag{14}$$

Thereinto, $\alpha_Y \in (0,1)$, $A_{Y,t}$ Indicates the total factor productivity of the sector. $K_{Y,k,t}$ and $N_{k,t}$Indicates the capital and labor used in production,$\xi_{Y,t}$An exogenous shock used to measure the quality of capital.

In each period, the final product producer sets the best price by selecting the best labor and energy inputs and through its monopolistic market position$P_{k,t}$,Thus achieving its goal of maximizing profits. The optimal equation for labor and energy demand is:

$$W_t = MC_t Y_t^{1/\varepsilon_Y} \varpi_{VA_Y}^{1/\varepsilon_Y} VA_{Y,t}^{(\varepsilon_Y-1)/\varepsilon_Y} (1-\alpha_Y) \frac{1}{N_t} \tag{15}$$

$$E_t = MC_t^{\varepsilon_Y} \varpi_E \left(\frac{P_{E,t}}{P_t}\right)^{-\varepsilon_Y} Y_t \quad (16)$$

$P_{E,t}$Indicates energy$E_t$nominal price,MC_tRepresents the marginal cost of production and is strictly less than 1, which is due to market distortion caused by monopolistic competition from producers of final goods. Because all manufacturers face the same optimization problem, remove the subscript k and find the optimal combination of energy demand from the cost minimization problem:

$$E_{L,t} = \varpi_{E_L} \left(\frac{P_{E_{L,t}}}{P_{E,t}}\right)^{-\varepsilon_E} E_t \quad (17)$$

$$E_{F,t} = \varpi_{E_F} \left(\frac{P_{E_{F,t}}}{P_{E,t}}\right)^{-\varepsilon_E} E_t \quad (18)$$

$P_{E_{L,t}}$ and $P_{E_{F,t}}$ The nominal prices of low-carbon energy and fossil energy are denoted respectively.

With reference to Rotemberg (1982), it is assumed that the price-adjusted cost function of the final product production department:

$$\Gamma_P(P_{k,t}) = (\gamma_p/2)\left[P_{k,t}/\left(P_{k,t-1}\Pi_{t-1}^{lp}\Pi^{1-lp}\right) - 1\right]^2 Y_t \quad (19)$$

$\Pi_t = P_t/P_{t-1}$,γ_P >0denotes the price adjustment cost factor,ΠIndicates the inflation trend and$l_p \in [0,1]$Indicates the degree to which past inflation has affected the current price index. The New Keynesian Phillips curve can then be obtained, that is, the optimal price setting of the manufacturer:

$$1 - \sigma_t - \gamma_P\left(\frac{\Pi_t}{\Pi_{t-1}^{lp}\Pi^{1-lp}} - 1\right)\frac{\Pi_t}{\Pi_{t-1}^{lp}\Pi^{1-lp}} + \beta E_t \Lambda_{t,t+1}\gamma_P\left(\frac{\Pi_{t+1}}{\Pi_t^{lp}\Pi^{1-lp} - 1}\right)\frac{\Pi_{t+1}}{\Pi_t^{lp}\Pi^{1-lp}}\frac{Y_{t+1}}{Y_t} + MC_{k,t}\sigma_t = 0 \quad (20)$$

At the end of the t period, the company sells the depreciated capital at a price$Q_{Y,t}$Purchased for t+1period of production of physical capital $K_{Y,t+1}$ .The company through the issuance of bonds$S_{Y,t}$Financing from a bank.Through market arbitrage, the value of the capital acquired by the firm is eventually equal to the value of the issued bonds:$Q_{Y,t}K_{Y,t+1} = Q_{Y,t}S_{Y,t}$.t+1 ending capital stock value$(Q_{Y,t+1} - \delta_Y)\xi_{Y,t+1}K_{Y,t+1}$, Here$\delta_Y > 0$Represents the rate of depreciation of capital.t+1The rate of return on capital paid by the company to the bank$R_{Y,t+1}$:

$$R_{Y,t+1} = \frac{(Q_{Y,t+1} - \delta_Y)\xi_{Y,t+1} + \frac{MC_{t+1}Y_{k,t+1}^{1/\varepsilon_Y}\varpi_{VA_Y}^{1/\varepsilon_Y}VA_{Y,t+1}^{(\varepsilon_Y-1)/\varepsilon_Y}\alpha_Y}{K_{Y,t+1}}}{Q_{Y,t}} \quad (21)$$

The rate of return on capital depends on the characteristics of the industry, the price of assets and the exogenous changes in the quality of capital. for measuring the quality of capital$\xi_{Y,t}$.A negative shock can cause the value of assets in the sector to fall.

The low-carbon energy sector is recorded as:L, Consists of perfectly competitive companies. Low-carbon energy production function:

$$E_{L,t} = A_L \xi_{L,t} K_{L,t} \tag{22}$$

Here$A_L$denotes total factor productivity,$\xi_{L,t}$denotes the quality of capital,$K_{L,t}$Indicates capital.

Similar to the final product factory division,at t Final,The company sells the depreciated capital and sells it at a price$Q_{L,t}$Purchased for t+1 production of physical capital$K_{L,t+1}$.The company through the issuance of bonds$S_{L,t}$financing from a bank to meet the capital needs required to purchase capital $Q_{L,t}K_{L,t+1} = Q_{L,t}S_{L,t}$ .The value of the capital stock at the end of the t+1 period$\left(Q_{L,t+1} - \delta_L\right)\xi_{L,t+1}K_{L,t+1}$, Here$\delta_L > 0$Indicates the rate of depreciation of capital.t+1The company pays the bank the rate of return on assets$R_{L,t+1}$:

$$R_{L,t+1} = \frac{\left(Q_{L,t+1} - \delta_L\right)\xi_{L,t+1} + \frac{P_{E_{L,t+1}}}{P_{t+1}} \frac{E_{L,t+1}}{K_{L,t+1}}}{Q_{L,t}} \tag{23}$$

The fossil energy sector is recorded F, Consists of perfectly competitive companies.Through hired labor$N_{F,t}$and lease capital$K_{F,t}$to produce intermediate goods$VA_{F,t}$, The intermediates produced by it are then used$VA_{F,t}$and natural resources$X_t$to produce the final product. Fossil energy production function:

$$E_{F,t} = \left[\varpi_{VA_F}^{1/\varepsilon_F} VA_{F,t}^{(\varepsilon_F-1)/\varepsilon_F} + \varpi_X^{1/\varepsilon_F} X_t^{(\varepsilon_F-1)/\varepsilon_F}\right]^{\varepsilon_F/(\varepsilon_F-1)} \tag{24}$$

Here $VA_{F,t} = A_F \xi_{F,t} K_{F,t}$, $\varepsilon_F > 0$ denote $VA_{F,t}$ and fossil resources X_t between the elasticity of substitution.$\varpi_{VA_F}$and$\varpi_X$is the corresponding weight.Capital purchases are financed from the same mechanism as in other sectors.t+1The rate of return on assets paid by the company to the bank$R_{F,t+1}$:

$$R_{F,t+1} = \frac{\left(Q_{F,t+1} - \delta_F\right)\xi_{F,t+1} + \frac{P_{E_{F,t+1}}}{P_{t+1}} \frac{E_{F,t+1}^{1/\varepsilon_F} \varpi_{VA_F}^{1/\varepsilon_F} VA_{F,t+1}^{(\varepsilon_F-1)/\varepsilon_F}}{K_{F,t+1}}}{Q_{F,t}} \tag{25}$$

From the above equation, we can see how the expected depreciation of fossil assets due to the negative impact on the asset quality of the fossil sector affects the current price of fossil assets.

It is assumed that fossil resources are abundant and carbon emissions are the same$X_t$correlationand exogenous prices$P_{X,t}$flexible supply.If climate policies are implemented, companies will pay the equivalent of each unit of fossil resources used in production$\tau_{X,t}$carbon tax.

At the end of each period, perfectly competitive sectors of capital production will be drawn from each sector $S \in (Y, L, F)$ The capital it sells is purchased, then the depreciated capital is refurbished and new capital is produced.Capital producers at prices$Q_{S,t}$At the same time, the

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renovation capital and the new capital were sold to the commodity and energy production sectors. I_S represents investment, then capital stock $K_{S,t+1} = \xi_{S,t}K_{S,t} + I_{S,t} - \delta_S\xi_{S,t}K_{S,t}$ .When producing new capital, there are investment adjustment costs $(\gamma_S/2)\left(I_{S,t}/I_{S,t-1} - 1\right)^2$,Over here$\gamma_S > 0$.The objective function of the producer of capital goods:

$$max\ E_0 \sum_{t=0}^{\infty} \Lambda_{0,t} \left[Q_{S,t}I_{S,t} - \left(1 + (\gamma_S/2)\left(I_{S,t}/I_{S,t-1} - 1\right)^2\right) I_{S,t}\right] \tag{26}$$

The first-order condition for maximizing the profits of capital producers yields the equation for determining the asset price:

$$Q_{S,t} = 1 + \frac{\gamma_S}{2}\left(\frac{I_{S,t}}{I_{S,t-1}} - 1\right)^2 + \gamma_S\left(\frac{I_{S,t}}{I_{S,t-1}} - 1\right)\frac{I_{S,t}}{I_{S,t-1}} - E_t\beta\Lambda_{t,t+1}\gamma_S\left(\frac{I_{S,t+1}}{I_{S,t}} - 1\right)\left(\frac{I_{S,t+1}}{I_{S,t}}\right)^2 \tag{27}$$

3.3. Banking Sector

In each period, banks raise deposits from households and lend money to the energy and end-product production sectors. The balance sheet of the bank in period t:

$$\sum_S Q_{S,t}S_{S,t}^P = NW_t + B_t^P \tag{28}$$

$Q_{S,t}S_{S,t}^P$Indicates the value of the bonds that the company needs to issue to the bank, that is, the value of the financing provided by the bank to the manufacturer.NW_tdenotes the net capital of the bank,B_t^PIndicates household savings.

In the t period, the bank receives a random income from the bonds issued by the company$R_{S,t}$, and pay interest to depositorsR_t.Net assets equal to the difference between income on assets and interest on liabilities:

$$NW_t = \sum_S R_{S,t}Q_{S,t-1}S_{S,t-1}^P - R_tB_{t-1}^P \tag{29}$$

Combining the above two equations, the dynamic equation of bank capital is obtained:

$$NW_t = \left[\sum_S (R_{S,t} - R_t)\frac{Q_{S,t-1}S_{S,t-1}^P}{NW_{t-1}} + R_t\right]NW_{t-1} \tag{30}$$

$R_{S,t} - R_t$Represents the risk compensation of the assets of the three departments. The main sources of changes in bank capital are interest rate differentials and fluctuations in asset prices. Banks can amplify their return on net assets by amplifying leverage. In order to limit the unlimited expansion of the bank's assets to the three sectors.reference Gertler&Karadi(2011)setting,Introduce financial friction with the problem of bankers' moral hazard. Bankers can transfer a portion of the bank's assets for their own use in each installment. If the bank fails to repay the depositor's debts on time, the depositor can force the bank to go bankrupt to liquidate it and obtain a portion of its assets. The incentive compatibility constraints faced by banks are:

$$V_t \geq \rho\left(Q_{Y,t}S_{Y,t}^P + \psi_L Q_{L,t}S_{L,t}^P + \Psi_F Q_{F,t}S_{F,t}^P\right) \tag{31}$$

V_tIndicates the present value of the expected return that the bank can expect from normal operations. The incentive compatibility constraint mechanism shows that households are willing to save only when the present value of the bank's expected return is greater than the value of the assets that can be misappropriated.ρ,$\rho\psi_L$,$\rho\psi_F$Respectively, bankers can transfer their shares of bonds in the final product sector, the low-carbon sector, and the fossil energy sector.$\psi_L$andψ_F separately exogenous risk-weighting factors for L sectors and F sectors.The higher the exogenous risk-weighting factor, the higher the risk premium.

Bellman equation for bank optimization:

$$V_{j,t} = \max_{\left\{S^P_{Y,j,t+1},S^P_{L,j,t+1},S^P_{F,j,t+1}\right\}} E_t \sum_{i=0}^{\infty} (1-\theta)\theta^i \beta^{i+1} \Lambda_{t,t+1+i} NW_{j,t+1+i} \tag{32}$$

In order to solve the bank optimization problem, it is assumed that the final wealth value and net assets are linear functions, and the linear functions faced by different banks are the same, ie$V_{j,t} = \upsilon_t NW_{j,t}$.$\upsilon_t$Indicates the shadow value of a bank's net assets.Under this assumption, Eq. (31) is written as follows:

$$\upsilon_t NW_{j,t} = \rho\left(Q_{Y,t}S_{Y,j,t} + \psi_L Q_{L,t}S_{L,t} + \psi_F Q_{F,t}S_{F,j,t}\right) \tag{33}$$

Combined with Eq. (29), write Eq. (32) as follows:

$$V_{j,t} = max\, E_t \left\{\beta\Lambda_{t,t+1}\left[(1-\theta) + \theta_{\upsilon_{t+1}}\right]\left[\sum_S \left(R_{S,t+1} - R_{t+1}\right)\frac{Q_{S,t}S_{S,j,t}}{NW_{j,t}} + R_{t+1}\right] NW_{j,t}\right\} \tag{34}$$

From the above equation, the risk-adjusted capital adequacy ratio of the bank can be obtained:

$$k_t = \frac{NW_t}{Q_{Y,t}S^P_{Y,t} + \psi_L Q_{L,t}S^P_{L,t} + \psi_F Q_{F,t}S^P_{F,t}} = \frac{\rho}{\upsilon_t} \tag{35}$$

3.4. Public Sector

The public sector consists of fiscal and monetary authorities. The fiscal sector mainly implements fiscal policy, while the monetary sector implements both monetary policy and macro-prudential policy.

For price-based monetary policy, it is assumed to obey Taylor's interest rate rule:

$$\frac{R_{N,t}}{R_N} = \left(\frac{R_{N,t-1}}{R_N}\right)^{li} \left[\left(\frac{\pi_t}{\pi}\right)^{l\pi} \left(\frac{Y_t}{Y_{t-1}}\right)^{ly}\right]^{1-li} \tag{36}$$

$R_{N,t}$ risk-free nominal interest rate, $l_i \in (0,1)$ is a smoothing parameter, $l_\pi > 0$ and $l_y > 0$ indicates the response of nominal interest rates to changes in inflation and output.

The central bank can raise funds in the form of short-term government bonds to purchase assets in the three sectors. Central Bank Balance Sheet:

$$\sum_{S} Q_{S,t} S_{S,t}^{G} = B_{t}^{G} \tag{37}$$

Budgetary constraints for the public sector:

$$T_t = C_t^G - \tau_{X,t} X_t - \sum_{S} \left(R_{S,t} - R_t\right) B_{t-1}^G \tag{38}$$

Here C_t^G denotes the consumption of the public sector, $\tau_{X,t}X_t$ indicates the increase in government revenues from the carbon tax,$R_t = R_{N,t-1}/\Pi_t$.

3.5. Market Clearing

The conditions for clearing the market in the financial markets are:$B_t = B_t^P + B_t^G$and$S_{S,t} = S_{S,t}^P + S_{S,t}^G$, $S \in \{Y, L, F\}$.The final output is used for consumption, government spending, new investment, and the cost of adjusting for investment and price changes, and the market clears it under the following conditions:

$$Y_t = C_t + C_t^G + \sum_{S} I_{S,t} + \sum_{S} \frac{\gamma_S}{2}\left(\frac{I_{S,t}}{I_{S,t-1}} - 1\right)^2 I_{S,t} + \frac{\gamma_P}{2}\left(\frac{\Pi_t}{\Pi_{t-1}^{lp}\Pi^{1-lp}} - 1\right)^2 Y_t \tag{39}$$

3.6. Exogenous Shocks

The carbon tax policy shock obeys the logarithmic AR(1) process;

$$ln\tau_{X,t} = \rho_{\tau_{X,t}} ln\tau_{X,t-1} + \varepsilon_{\tau_{X,t}}, \varepsilon_{A_t} \sim N\left(0, \sigma_{\tau_{X,t}}^2\right) \tag{40}$$

The quality of capital in all three sectors obeys the logarithmic AR(1) process:

$$ln\xi_{Y,t} = \rho_{\xi_{Y,t}} ln\xi_{Y,t-1} - \varepsilon_{\xi_{Y,t}} - \kappa\varepsilon_{\xi_{F,t}}, \varepsilon_{\xi_t} \sim N(0, \sigma_{\xi_Y}^2) \tag{41}$$

$$ln\xi_{L,t} = \rho_{\xi_{L,t}} ln\xi_{L,t-1} + \varepsilon_{\xi_{L,t}} - \varepsilon_{\xi_{Y,t}}, \varepsilon_{\xi_t} \sim N\left(0, \sigma_{\xi_L}^2\right) \tag{42}$$

$$ln\xi_{F,t} = \rho_{\xi_{F,t}} ln\xi_{F,t-1} - \varepsilon_{\xi_{F,t}} - \varepsilon_{\xi_{Y,t}}, \varepsilon_{\xi_t} \sim N\left(0, \sigma_{\xi_F}^2\right) \tag{43}$$

This paper sets up the rationale for the exogenous shock to capital quality: when a carbon tax policy is implemented, fossil sector assets will be negatively affected as carbon-intensive assets. Production sector Y, as an upstream enterprise in fossil fuel sector F, will also be affected by the negative shock, but to the extent that it will be affectedκDepends on the share of intermediates in the fossil sector that are owned and used.Low-carbon sector L and fossil sector F are also affected by production sector Y. When the production sector Y is negatively impacted by asset quality, the scale of production will also be negatively impacted, which will lead to a decrease in the demand for production factors, resulting in another negative impact on the asset quality of the two sectors.

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4. Parameter Calibration

4.1. Parameter Calibration

In this paper, the static structural parameters are calibrated according to the actual data in China and mainstream literature. According to data provided by Trading Economics, the steady-state value of the country's total inflation rate is calibrated to 1.005. The steady-state value of the output is normalized to 1. According to the data provided by the 2022 China Statistical Yearbook, the steady-state value of consumption is calibrated to 0.543. Referring to Zhang et al. (2022), the steady-state value of China's carbon emissions was calibrated to 0.2. According to most literature, the steady-state value of labor supply is calibrated to 1/3.Referring to Liu Bin (2008), the subjective discount factor of residentsβ calibrated to 0.99； Referring to Lu et al. (2020), the elasticity of capital outputα_YCalibrated to 0.35,The investment adjustment costs of the three sectors are calibrated to 10.Refer to Xu Piaoyang (2022) to adjust the price to the cost factor$\gamma_P$calibrated to 60,According to estimates, from 2000 to 2020, the average proportion of China's energy consumption in GDP is21.75%.According to relevant studies, more than 60% of energy consumption is used in industrial production, so the proportion of energy in the final product production sector will be used$\varpi_E$calibrated to 0.13.According to the 2022 National Bureau of Statistics data, clean energy consumption accounts for 25.9% of total energy consumption, so the share of clean energy in the energy package ϖ_{E_L} Calibrated as 0.259.Referring to Diluiso et al. (2021), the share of natural resources in fossil energy productionϖ_XCalibrated to 0.3.Referring to Cheng Yutai et al. (2022), the final product will replace elasticityσcalibrated to 6.Refer to Carattini et al. (2021) on the alternative resilience of green and brown energyε_E calibration of 2 indicates an incomplete substitution between the two.Refer to KalKuhl et al. (2012).$VA_Y$and $E$of alternative elasticity $\varepsilon_Y$calibrated to 0.5,$VA_F$and X of alternative elasticity ε_F calibrated to 0.3.The annual capital depreciation rate of department Y is calibrated to 10% and the quarterly depreciation rate is 2.5%, while the quarterly depreciation rate of department F is calibrated to 1.25% and the quarterly depreciation rate of department L is 2%, according to Baldwin et al. (2020). Most of the references refer to the bank survival probability between [0.94 , 0.98], and the bank survival probability is 0.96. Referring to Xu Piaoyang (2022), the risk premium for banks in the intermediate commodity production sector, fossil energy sector, and clean energy sector is calibrated to 0.0060.007 and 0.0072.Set a capital adequacy ratio of 8% with reference to the Basel III minimum capital adequacy requirements.

4.2. Parameter Estimation

In this paper, four observed variables are selected for Bayesian estimation of the remaining parameters: output, consumption, inflation rate, and interest rate. From the first quarter of 2001 to the third quarter of 2023, GDP, total retail sales of consumer goods, CPI and the weighted average interest rate of interbank lending (three months) are selected, and the data are from China Economic Network and the National Bureau of Statistics. In this paper, the steps of processing the relevant data are as follows: the quarterly time series data of G DP and the total retail sales of social consumer goods are seasonally adjusted using the X12 method, and the seasonally adjusted data is logarithmic. Then, the unilateral HP filtering method was used for detrending. The headline inflation rate is calculated and adjusted for the monthly CPI data, and the total nominal interest rate is calculated and adjusted for the monthly data of the weighted average interbank rate (three months). Inflation and nominal interest rates are stationary variables that are directly equivalent to the variables in the model. The prior distribution settings in this paper refer to the classical literature, and the Bayesian estimation results are summarized in Table 1.

Table 1. Bayesian estimation results

paramet	priori distrib	Prior mean	Prior s.d	Posterior mean	Posterior s.d
h_C	Beta	0.5	0.05	0.3914	0.0676
ζ	Gamma	1.5	0.05	1.4256	0.0054
φ	Gamma	1.0	0.05	1.0036	0.0374
l_y	Normal	0.125	0.05	0.2322	0.0491
l_π	Normal	1.5	0.25	2.0078	0.0198
l_i	Beta	0.7	0.02	0.6902	0.0329
l_P	Beta	0.5	0.05	0.3914	0.0222
ρ_{AY}	Beta	0.8	0.1	0.8358	0.0025
ρ_{AL}	Beta	0.8	0.1	0.8378	0.0098
ρ_{AF}	Beta	0.8	0.1	0.8330	0.0082
ρ_{ξ_Y}	Beta	0.8	0.1	0.9950	0.0022
ρ_{ξ_L}	Beta	0.8	0.1	0.9918	0.0032
ρ_{ξ_F}	Beta	0.8	0.1	0.8070	0.0118
$\rho_{\tau_{X,t}}$	Beta	0.8	0.1	0.9036	0.0021
σ_{AY}	Inv.Gamma	0.01	4	0.0867	0.0111
σ_{AL}	Inv.Gamma	0.01	4	0.0682	0.0584
σ_{AF}	Inv.Gamma	0.01	4	0.0109	0.0057
σ_{ξ_Y}	Inv.Gamma	0.01	4	0.0148	0.0191
σ_{ξ_L}	Inv.Gamma	0.01	4	0.0276	0.0042
σ_{ξ_F}	Inv.Gamma	0.01	4	0.0931	0.0155
$\sigma_{\tau_{X,t}}$	Inv.Gamma	0.01	4	0.0099	0.0072

5. Numerical Simulation and Mechanism Analysis

This section explores the transition risks that may arise from carbon tax policies and discusses in detail the relationship between stranded assets and transition risks. When a one-unit standard deviation carbon tax shock is introduced, the dynamic response of the major economic variables is shown in Figures 1 and 2(both impulse response plots are expressed as percentages of deviation from the steady-state value).

As far as the production sector is concerned. With the introduction of a carbon tax, the rise in fossil fuel prices has pushed up the cost of production inputs, leading to a contraction of production in the initial period of the final production sector and a decrease in fossil energy demand. The decline in the demand for fossil energy leads to a decrease in the demand for factors in the fossil energy sector.Make intermediates$VA_{F,t}$and reduced demand for fossil fuels,This is conducive to carbon reduction.The substitution effect of the energy market increases the demand for low-carbon energy in the final production sector, driving up the price of low-carbon energy, and thus increasing investment in the low-carbon energy sector. The prices of low-carbon energy and fossil energy are both rising first and then falling. At the end of the simulation period, total energy prices were still 1.4% above the steady-state value, and total energy demand was still down by 0.06% (the decrease in energy demand brought about by the income effect is greater than the increase in energy demand brought about by the substitution effect, and the possible reason why the income effect is greater than the substitution effect is that fossil energy and low-carbon energy are not completely replaced, and fossil energy accounts for a large share of energy input). In the initial phase, the negative impact of the energy market was partially offset by an increase in demand for intermediate goods consisting of labour and capital (the production sector opted for cheaper inputs to factors of production), resulting in a relatively limited initial decline in output. As we can see from the dynamics in Figure 1, the pressure of rising energy prices and falling asset values has led to a further deterioration in output in the final production sector, resulting in a consequent decrease in demand for intermediate goods made up of labour and capital. However, at the end of the simulation period, labor still rose by 0.1% (output recovered, and energy prices remained above steady-state levels). In the initial phase, the increase in the demand for labor in the final goods production sector leads to an initial rise in wages. At this time, it is expected that future wage cuts will increase savings and reduce consumption, leading to an initial decline in consumption. In the initial stages, wage and energy prices have risen, leading to cost-push inflation. The contraction in output was accompanied by a contraction in wages offsetting the pressure of rising energy prices, leading to a period of deflation (inflation around the tenth period below steady-state levels). At the end of the simulation period, inflation remained above the steady-state value of 0.02%.

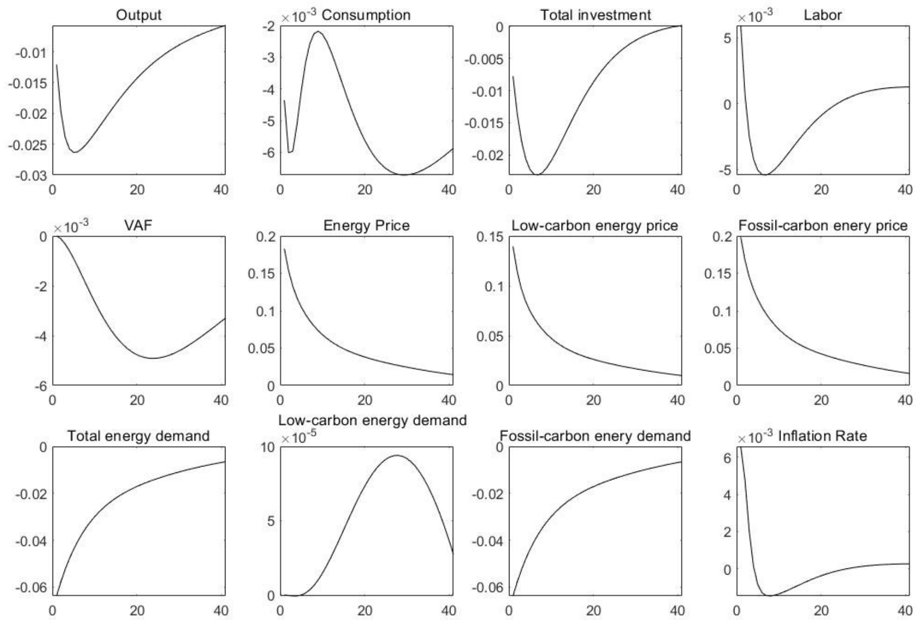

Figure 1. The impact of carbon taxes on macroeconomic

As far as the financial sector is concerned. With the introduction of carbon tax, the reduction in demand for fossil fuels has negatively impacted the capital quality of the sector, resulting in a decrease in the amount of effective capital in the sector and inhibiting the asset value of the sector. The decline in effective capital and the decline in the value of assets have affected the sector's ability to raise funds from banks and discouraged investment in the sector. The sector's capital quality was negatively impacted due to reduced energy demand due to the contraction in initial production, resulting in an initial decline in the sector's asset values. With the increase in demand for low-carbon energy, the capital quality of the low-carbon sector has been positively impacted, and the effective capital of the sector has risen, which has boosted the investment and asset values of the sector (above the steady-state level in the medium term). As an upstream enterprise in the fossil energy sector, the capital quality of the final production sector has been negatively impacted, resulting in a decrease in the amount of effective capital in the sector and inhibiting the asset value of the sector. The decline in effective capital and the decline in the value of assets have affected the sector's ability to raise funds from the banking sector, discouraging investment in the sector. In the initial period, the deterioration of the balance sheet led to an increase in bank leverage due to a decrease in the net assets of the banking sector due to a decline in the asset value of the three sectors. However, the deterioration of banks' balance sheets has been offset to some extent by the rise in the value of assets in the low-carbon sector. The banking sector sells off fossil energy assets and end-production sector assets to reduce leverage, which leads to a further decline in the value of assets in both sectors. Due to the decline in the effective capital and asset value of the fossil energy sector and the final goods production sector, banks will demand higher risk compensation from both sectors, resulting in higher interest spreads in both sectors. This also raises the marginal cost of the production sector, leading to further contraction of investment and output. This also explains the further decline in the initial period of the main economic variables such as output and investment. At the end of the simulation period, capital in the fossil energy sector and final production sector fell by 6% and 14%, respectively, which was partly offset by an increase in capital in the low-carbon sector. At the end of the simulation period, capital in the low-carbon sector increased by 0.5 per cent. It can be seen that the banking sector could amplify this risk and achieve a circular transmission from entity-finance-entity, thereby further damaging the economy. This circular pattern of transmission is highly susceptible to systemic risk, resulting in a "Minsky moment" (Breeden, 2019).

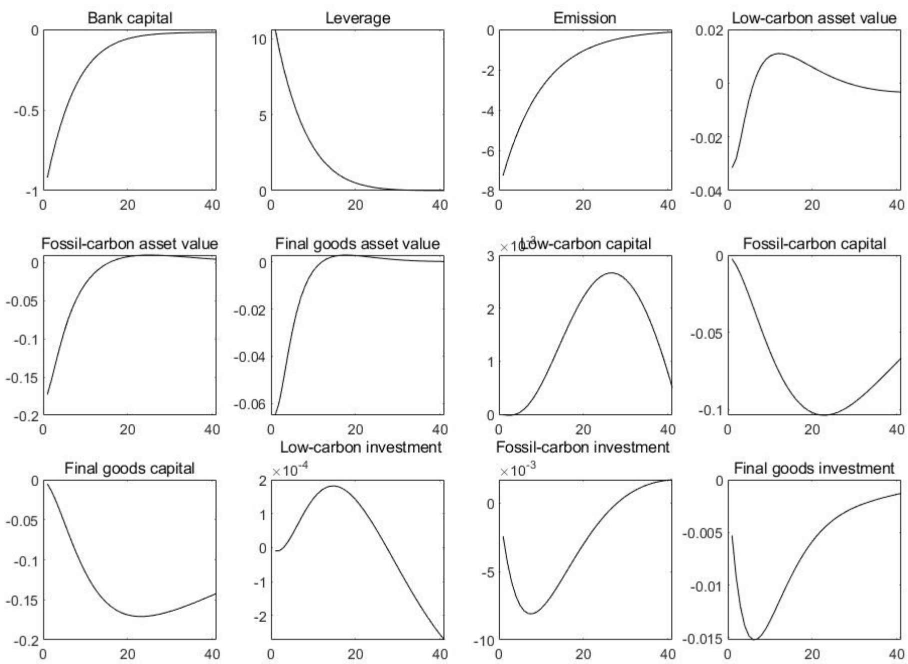

Figure 2. The impact of carbon taxes on financial stability

As the effect of the carbon tax gradually weakens, the major economic variables are gradually recovering. At the end of the simulation period, output, total investment and consumption fell by 0.57%, 0.01% and 0.58%, respectively. Net assets and leverage decreased by 1.7% and increased by 0.7%, respectively. Carbon emissions fell by 12.9%.

The results of this part of the simulation show that: First, carbon taxes mainly affect macroeconomic and financial stability by affecting energy prices and asset values. Second, the carbon tax policy restricts carbon emissions from the production side by increasing the production cost of brown enterprises, which has a good climate governance effect, but the carbon tax policy will lead to certain transition risks. Third, the carbon tax policy has a negative impact on the value of carbon-intensive assets by affecting asset quality. The presence of stranded assets has severely eroded bank assets, negatively affecting financial stability. This negative impact is complex and severe. In addition to the depreciation of the fossil energy sector's own assets, the upstream and downstream industries and assets related to it are also facing the impact of asset depreciation. The negative impact of stranded assets on financial stability can lead to macroeconomic volatility through the interaction between finance and the real economy, forming a vicious circle.

6. Regulatory Response to Transition Risks

6.1. Monetary Policy

The implementation of climate policy is not only a climate governance issue, but also an important economic issue. How to balance carbon emission reduction and economic development has also become a key issue for scholars. In this context, it is of great significance to study the monetary policy that takes into account carbon emission reduction and macroeconomic development. This paper integrates carbon tax policy and monetary policy into a unified framework through the DSGE model, and compares and analyzes the impact of carbon tax policy on macroeconomic and financial stability under different monetary policy rules. The specific currency rules are set as follows M_1 for the standard Taylor rule:l_π =1.5, $l_y = 0.125$, $l_{RN} = 0$.Under this setting, the monetary authority anchors inflation and output.M_2 for taylor rule for a single goal 1: l_π =3, $l_y = 0$, $l_{RN} = 0$.Under this scenario, the monetary authority only anchors inflation as its target and pays high attention to inflation. M_3 for taylor rule for a single goal 2: l_π =1.5, $l_y = 0$, $l_{RN} = 0$. Under this setting, the monetary authority only anchors inflation as the anchor target.Inflation concerns with M_1 same and comparative M_2 weak.

Table 2. The impact of carbon tax on macroeconomic and financial stability under different monetary policy rules

	Baseline	M_1	M_2	M_3
Output loss	0.005 7	0.005 8	0.006 3	0.005 9
Output s.d	0.105 6	0.105 8	0.116 9	0.107 5
Inflation s.d	0.009 4	0.015 2	0.007 1	0.014 4
B.C loss	0.017 4	0.018 0	0.020 2	0.018 4
B.C s.d	1.849 5	2.033 3	2.729 5	2.136 3

As can be seen from Table 2, inflation volatility is the least under a single strong inflation target, which has the best effect on price stability. However, the loss of output and the widening of output fluctuations are not conducive to the recovery of production. At the same time, the loss of net assets and the widening volatility of net assets are not conducive to financial stability. Monetary policy targets that are less responsive to inflation are likely to bring higher inflation volatility under carbon tax shocks. The inflation pegging coefficient is the same, but the monetary policy target is different M_1 and M_3, M_3 is less effective for output recovery and financial stability M_1 .but The effect on M_3 price stability is relatively high M_1 ,Possible reasons: M_1 price fluctuations due to the recovery of output.Overall, monetary policy that anchors both output and inflation has a better effect on economic recovery and financial stability than monetary policy that only anchors inflation. Looking at the losses and fluctuations of major macroeconomic variables, monetary policy that is anchored only to the inflation target will adversely affect output and total investment. From the perspective of financial stability, anchoring the inflation target alone leads to a further decline in banks' net assets and widens the volatility of banks' net assets, exacerbating the financial risks faced by banks. Monetary policy compared to anchored output and inflationM_1, Benchmark monetary policy, which takes into account interest rate smoothing, performs better in terms of price stability, economic recovery, and financial stability. Overall, the monetary policy of the benchmark model has performed better in balancing carbon emission reduction and economic development.

The simulation results of this part show that: first, although the Taylor rule, which only anchors inflation, has a certain effect on price stability, it also exacerbates the transition risk; Second, the standard Taylor rule performs better at mitigating transition risks than monetary policy that only anchors inflation targeting. However, the standard Taylor rule does not perform well in mitigating transition risks compared to benchmark monetary policy, which considers interest rate smoothing. Third, there is no big difference in the effect of carbon emission reduction between the four monetary policy rules set above, but there is a big difference in the impact on economic development.

6.2. Macro-prudential Policy

Numerical simulations show that the carbon tax policy will cause a certain degree of transition risk, which provides a basis for integrating transition risk into the financial regulatory framework. Based on the basic model, macro-prudential policies such as capital supervision are introduced, and the impact of different regulatory measures on macroeconomic and financial stability is explored by adjusting the capital risk weight of banks. At the same time, the regulatory measures are non-neutral, so that the impact of such non-neutral regulatory measures on carbon emission reduction can be further observed. Adjust the capital adequacy ratio formula in the model as follows:

$$k_t = \frac{NW_t}{Q_{Y,t}S_{Y,t}^P + \mu_L\psi_L Q_{L,t}S_{L,t}^P + \mu_F\psi_F Q_{F,t}S_{F,t}^P} \tag{44}$$

Hereμ_L, $\mu_F$represents the corresponding risk weight.$\mu_L < 1$ on behalf of the green support regulatory policy,When the risk weight of green assets is reduced, the balance sheet is eased, which will guide more funds to invest in green industries. $\mu_F > 1$represents the regulation of brown penalties, when the risk weight of brown assets is increased, the balance sheet of banks becomes more stressed, which reduces brown investments.In this paper, the following three scenarios are numerically simulated: first, when the risk weight of assets in the low-carbon sector is reduced by 20%,namely $\mu_L = 0.8$, Macroprudential policies that express green support S_1 .Second, when the risk weight of brown sector assets is increased by 20%,namely$\mu_F = 1.2$, indicating a macroprudential policy of brown punishmentS_2. The third is the macroprudential policy that uses both brown penalties and green supportS_3, namely$\mu_L = 0.8, \mu_F = 1.2$ .To assess the effectiveness of macroprudential regulatory policies, Figures 3 illustrate the impact of carbon tax shocks on macroeconomic and financial stability under different macroprudential regulatory policies.

Table 3. The impact of carbon tax on macroeconomic and financial stability under the "two-pillar" framework

	Baseline	S_1	S_2	S_3
Output loss	0.005 7	0.005 4	0.005 9	0.005 6
Output s.d	0.105 6	0.105 5	0.103 3	0.105 1
Inflation s.d	0.009 4	0.008 6	0.009 8	0.009 5
B.C loss	0.017 4	0.016 7	0.024 3	0.018 8
B.C s.d	1.849 5	2.153 4	1.699 1	1.814 7

The first is the macroprudential policy of using green support alone. Under the macro-prudential policy supported by green, bank credit conditions have been relaxed, financing conditions in the three sectors have improved, and investment in the three sectors has increased, which has alleviated the pressure of the economic downturn to a certain extent. However, this non-neutral regulatory policy will change investors' expectations of brown assets, further reducing the value of brown assets, which will lead to greater volatility in banks' net assets. Initial leverage is too high and can threaten financial stability.

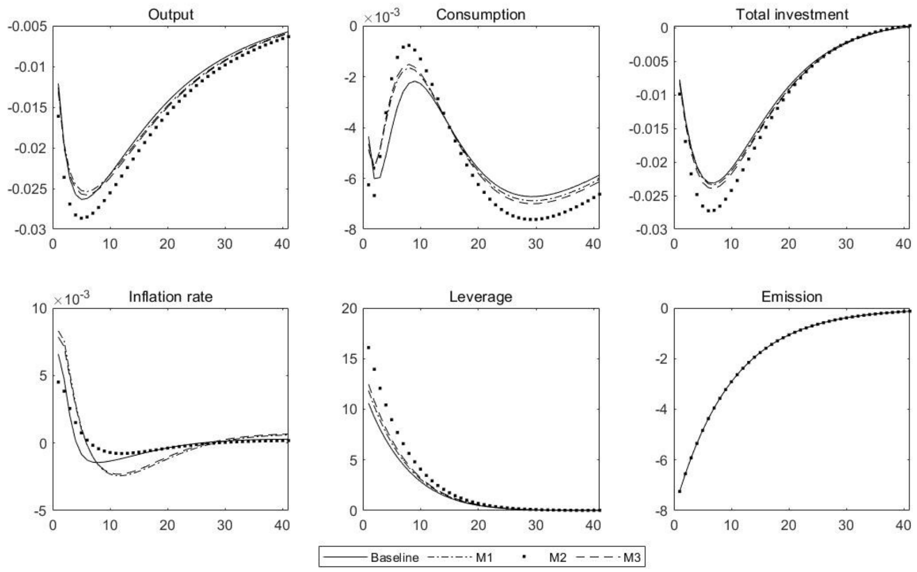

Figure 3. The impact of a carbon tax, monetary policy, and macroprudential policy mix on macroeconomic and financial stability

The second is the macroprudential policy of using brown penalties alone. Compared with green support for macro-prudential policies, the volatility of banks' net assets is smaller, which reduces the transition risks faced by banks and has a better effect on financial stability. Because the macroprudential policy regulation of brown penalties is directly aimed at depreciating assets. This regulatory plan has effectively led to a reallocation of bank portfolios, making banks more resilient to the depreciation of fossil assets. Again, as a side effect, total investment and output have fallen further. Strict capital requirements prevent banks from starting to expand their assets during the recovery phase, prolonging periods of economic downturns. In terms of specific values, the macroprudential effect of the brown penalty has been effective in reducing the volatility of output and net assets, but it has also increased the volatility of inflation.

The third is a macro-prudential policy that uses a combination of green support and brown punishment. After the implementation of the carbon tax, the magnitude of losses and fluctuations of the main economic variables are between the above two scenarios.

The results of this part of the simulation show that brown-penalized macroprudential policies perform better in terms of financial stability than green-supported macroprudential policies. But brown-penalized macroprudential policies have limited banks' ability to expand credit through strict capital requirements, prolonging the economic recovery. Green-backed macroprudential policies have performed better in the economic recovery, but have also exacerbated financial risks.

6.3. Welfare Analysis of "Two-Pillar" Policies

This part analyzes and compares the social welfare of different policy combinations to find the minimum welfare loss of the economy under different policy combinations, so as to determine the optimal "two-pillar" policy combination. In this paper, the social welfare loss function is set as:

$$W_L = \frac{1}{2}\left(\lambda_\pi var(\pi) + \lambda_y var(y) + \lambda_\phi var(\phi)\right) \tag{45}$$

λ_π, λ_y, λ_ϕThey represent weighted parameters for inflation, output, and financial variables (leverage).Referring to the research of Li Tianyu et al., will λ_π, $\lambda_y$and$\lambda_\phi$set to 1, 0.5, and 0.1, respectively.Based on the above welfare loss functions and parameter settings, the unconditional welfare loss under each policy combination is shown in Table 4.

Table 4. Welfare losses of the carbon tax, monetary policy and macroprudential policy mix

	Welfare lossW_L
Baseline	22.505
Carbon policy+M_1	27.511
Carbon policy +M_2	50.181
Carbon policy +M_3	30.447
Baseline +S_1	28.379
Baseline +S_2	20.303
Baseline +S_3	21.535

Table 4 shows the unconditional welfare losses under different policy mixes in the face of carbon tax shocks. thereinto$W_L$the lower the value, the higher the level of social welfare.As can be seen from Table 4, compared with the combination of carbon tax and monetary policy, the combination of macro gentleman's policy has a significant welfare improvement effect.thereinto Carbon tax and M_2 policy mix has the lowest level of social welfare, probably because the monetary policy that is only anchored to inflation comes at the cost of certain economic losses and financial risks, which leads to greater social welfare losses. Compared with monetary policy that only anchors inflation, monetary policy that anchors both output and inflation has relatively small social welfare losses, because monetary policy can help to restore and stabilize output.Base model and S_2The policy mix has the highest level of social welfare, probably because brown macroprudential regulatory policies limit banks' risk exposure and maintain financial stability to some extent.But the base model and S_1compared to the base model and carbon tax and $M_1$of higher welfare losses,The probable reason is that this green-backed macroprudential policy has eased banks' credit conditions and increased bank leverage. At the same time, this non-neutral regulatory measure has changed people's expectations of asset prices, leading to further expansion of banks' risk exposure, exposing banks to greater financial risks.Base model and S_3 compared with the basic model, there is a certain welfare improvement, but the effect of welfare improvement is higher than that of the basic model and S_2.Through the comparative analysis of welfare losses, the following conclusions can be drawn: First, the macroprudential policy of introducing brown punishment can help to improve social welfare. Second, the effect of welfare improvement brought about by different policy combinations is quite different, so policy authorities should weigh the relevant risks and introduce a well-designed policy mix when formulating relevant policies.

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7. Conclusion and Recommendations

In this paper, we construct a new Keynesian dynamic stochastic general equilibrium model that includes climate policy, asset quality, financial friction, and "two-pillar" policy. Based on this analytical framework, this paper studies the possible transition risks arising from the carbon tax policy and explores the relationship between stranded assets and transition risks. On this basis, the role of "dual-pillar" policies in coping with transition risks is further evaluated, and the optimal policy collocation is found through comparative analysis of social welfare.

The following conclusions are drawn: (1) The carbon tax policy has obvious effects on climate governance, but the carbon tax policy may cause certain transition risks. Carbon taxes have an impact on financial stability and the macroeconomy, mainly through energy prices and asset prices, and stranded assets play an important role in transition risks. (2) Monetary policy that only anchors inflation has a better effect on price stability, but this comes at the cost of a certain amount of output loss and financial fluctuations. Monetary policy anchored to output and inflation can effectively weigh output losses and price volatility in response to carbon tax shocks. Monetary policy, which takes into account the smoothing of interest rates, has the best effect on improving social welfare. (3) Brown-penalized macroprudential policies can effectively mitigate transition risks and improve social welfare by reducing the risk exposure of the financial sector. Green-backed macroprudential policies can help mitigate output losses, but they face greater financial risks, leading to further welfare losses. The macroprudential policy of combining green support and brown punishment has a certain welfare improvement effect.

Based on the above conclusions, this paper gives the following policy suggestions: (1) Although the carbon tax policy has a certain negative impact on the macroeconomy, its emission reduction effect is significant, and it is still an effective emission reduction tool in the international community, and the carbon tax policy is conducive to China's realization of the "double carbon" goal, so it is recommended that the relevant departments explore different schemes for the introduction of carbon tax. It is necessary to attach great importance to the transition risks that may be brought about by the carbon tax, do a good job in the relevant risk assessment and monitoring after the carbon tax is collected, and find a stable and orderly carbon tax collection plan. Financial institutions should identify and quantify stranded assets in advance, and carry out risk diversification and transfer through financial instruments such as insurance and risk transfer agreements in a timely manner. (2) The monetary policy authorities and the fiscal authorities should work closely together to deal with the risks that may be brought about by the carbon tax policy. Monetary policy authorities should find appropriate monetary policy tools in light of their own policy objectives to reduce the economic losses caused by climate policies. (3) Before the implementation of the carbon tax policy, the "two-pillar" policy should be improved and established in advance. The financial sector, the monetary sector and the financial regulatory authorities should further strengthen communication and coordination, comprehensively consider the overall effect of the carbon tax policy, monetary policy and macro-prudential policy combination, and introduce a well-designed policy portfolio according to their own roles, so as to effectively control the relevant risks in the implementation of the carbon tax.

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