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Theory and Singapore's Initiatives

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Sustainability-Linked Monetary Policy: Theory and Singapore's Initiatives

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Abstract

The financial sector in Singapore is now playing its part in promoting sustainability. Our survey of existing initiatives in Singapore finds that the Monetary Authority of Singapore has effectively led these sustainability initiatives, resulting in expanding volume of green and sustainability-linked loans. We further propose a sustainability-linked monetary policy framework via which the financing costs of entrepreneurs vary counter-cyclicly with environmental conditions. Our simulation results show that such a framework fulfills the dual mandate of welfare maximization and sustainability.

Keywords: Sustainability, Monetary policy, New Keynesian model, Environmental policy, Central bank, Green finance
JEL Codes: E32, E50, Q58

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1 Introduction

Climate-related risks have received growing attention from policy makers in recent years (Dikau and Volz, 2021; Muller, 2021). Central banks and the financial sector are believed to be capable of promoting sustainability effectively. Providing loans based on enterprises' environmental friendliness is one of the many ways to achieve the sustainability goal. Such sustainability-linked loans are becoming popular (see MAS, 2021b; LMA, 2019; DBS, 2021). The proliferation of such sustainability-linked loans means that monetary policy now has an additional mandate of promoting sustainability.

The objectives of this paper are twofold. First, we take stock the latest initiatives by Singapore's financial sector in promoting sustainability. As a resource-constrained city-state surrounded by the sea, Singapore cannot be more concerned about the issues of a rising sea level and limited resources. The financial sector, being the source of funding driving economic activity and production in the nation, has started to deliberately encourage projects that are more environmentally friendly. We take a brief overview of the status quo.

Second, we propose a monetary policy framework with a *sustainability-linked Taylor rule* (SLTR). It augments the conventional Taylor rule with a counter-cyclical response to environmental conditions. Via the SLTR, the varying financing costs for production due to environmental conditions incentivize firms to reduce capital inputs, hence reducing emissions. We examine the welfare implications of this monetary policy and find that the SLTR fulfills the dual mandate of welfare maximization and sustainability. Our work complements the vast literature on environmental policy, providing a stylized model for future research on an environmentally friendly monetary policy framework.

2 Initiatives by Singapore's financial sector

Following the COVID-19 pandemic, discussions to integrate the recovery process with a focus on environmental, social and governance (ESG) factors have gained ground globally. The recent unveiling of the Green Plan 2030 showcases Singapore's commitment towards advancing sustainability agenda in national development (Singapore Green Plan 2030, 2021). Green Plan 2030 targets Singapore to peak carbon emission in 2030 and achieve net zero carbon emission when viable after 2050. With the objective of building Singapore into a green finance hub for the region, Green Plan 2030 also has mandates in green finance.

To achieve a sustainable future, it is imperative for capital to be channeled to green technologies and green infrastructure. Monetary Authority of Singapore (MAS) recognizes this tantamount role played by finance sector as it aims to "make sustainable finance a defining feature of Singapore's role as an international financial centre, just as wealth management and FinTech have become"(MAS, 2021c). MAS's efforts at sustainable finance was initiated as early as 2017 when Green Bond Grant Scheme was launched to promote the issuance of green bonds. Singapore's strong commitment to sustainable finance became more evident with the Green Finance Action Plan that aimed to increase the resilience of financial sector to environmental risks, develop green financial solutions, and leverage innovation and technology. The Green Action Finance Action Plan was immediately followed by US$2 billion Green Investments Program to invest in funds with a strong green focus.

A notable strategy within the umbrella of the Green Finance Action Plan pertains to the Green and Sustainability-Linked Loan Grant Scheme (GSLS) which seeks to encourage green and sustainability-linked loans (MAS, 2021a). Green loans exclusively finance or re-finance eligible green projects. Sustainability-linked loans corresponds to a different context as such loans encourage borrowers to achieve sustainability performance targets (SPTs). This is achieved through aligning the loan terms to the borrower's performance against these SPTs – for example, borrowers are rewarded with a reduction in the loan interest rate if their SPTs are met.

The grants from GSLS supports both businesses and banks to transition to a green or sustainability-linked loan framework through three channels. First, GSLS provides support to Singapore corporates of all sizes to cover the expenses of engaging independent service providers to validate the green and sustainability credentials of the loan. MAS will defray up to S$100,000 of these expenses per loan. Second, GSLS also encourages Singapore banks to develop green and sustainability-linked loan frameworks. MAS will cover bank's expenses on engaging independent sustainability assessment and advisory service providers to develop frameworks, obtain external reviews, and report on the allocated proceeds of loans originated under the framework. MAS will cover up to 60% of these expenses, capped at S$120,000 for such green and sustainability-linked loan frameworks. Finally, GSLS also provides further incentive for banks to make such loan frameworks accessible to small and medium-sized enterprises (SMEs). MAS will cover 90% of the expenses towards frameworks specifically targeted at SMEs and individuals, capped at S$180,000 per framework.

After GSLS was launched, prominent banks like BNP Paribas, OCBC Bank, UOB and DBS have introduced green and sustainability-linked loan frameworks with standardized criteria for green and sustainable lending to corporates (MAS, 2021). These loans supports the financing of circular economy projects, renewable energy, energy efficiency activities and promote sustainable supply chain practices of large corporates and SMEs.

Figure 1: Green and Sustainability-linked Loan Volumes in Singapore (2017-2020)
Source: Monetary Authority of Singapore

According to Fig. 1, green and sustainability-linked loans have grown exponentially in Singapore since 2017. While green loan volumes constitute a large proportion of Singapore's sustainable loan market, sustainability-linked loans are also gaining momentum. Recently, PSA Marine secured sustainability-linked loan amounting to 30 million euro from DBS that featured an interest rate adjustment linked to ESG targets. The ESG target of the PSA Marine loan included deployment of PSA Marine's Crew Transfer Vessels to support offshore wind energy-related activities.

These initiatives by the banks in Singapore present a new transmission channel in monetary policy. As summarized by a quote from DBS website, banks "can promote sustainable development through such loans by pegging the interest rate of a credit facility to a series of environmental, social and governance (ESG) performance metrics. If pre-determined targets are achieved, the interest of the loan will be reduced." As with all other loans, the sustainability-linked loans use either the volume of loan provision or the loan interest rate as the key variable to incentivize enterprises to move towards cleaner production. Motivated by the initiatives by the banks, we develop a stylized monetary policy framework that is linked to sustainability.

3 A sustainability-linked monetary policy framework

Our model environment is based on Annicchiarico and Di Dio (2015), Heutel (2012) and Iacoviello and Neri (2010). There are two types of agents in the economy, savers and entrepreneurs. Savers lend their savings to entrepreneurs. The latter use the former's savings to finance their production. The profits from production are evenly distributed back to the savers and entrepreneurs as dividends. There are two types of capital inputs. The dirty capital input emits carbon dioxide while the clean capital input does not. They are substitutes in production. Abatement efforts to reduce emissions incur costs to the firms.

There are two policy makers. The environmental agency may chose to maintain a constant carbon tax (henceforth CC) and allow firms to derive their desired level of emission. Alternatively, a cap-and-trade policy (henceforth CT) can be implemented, in which case the emission quota is fixed and firms trade the emission permits at market prices. The central bank correspondingly adopts a version of the SLTR to influence the entrepreneurs' financing costs as environmental conditions change.

Savers A typical saver derives utility from consumption and disutility from labor supply. Her objective is to maximize the lifetime utility:

$$\mathbb{E}_t \sum_{t=0}^{\infty} \beta_s^t u\left(c_{st}, n_{st}\right) z_t, \tag{1}$$

where

$$u\left(c_{st}, n_{st}\right) = (1-\upsilon) \log\left[c_{st} - \upsilon c_{st-1}\right] - \mu_n \frac{{n_{st}}^{1+\varphi}}{1+\varphi}. \tag{2}$$

c_{st} is the saver's consumption bundle, n_{st} is the labor supply, z_t is a preference shock common to all agents in the economy, β_s is the discount factor of the saver, υ is the degree of habit persistence, φ is the inverse of the Frisch elasticity and μ_n is the weight of labor in the saver's utility. The budget constraint in each period is given by:

$$c_{st} + b_{st} = \frac{i_{t-1}}{\pi_t} b_{st-1} + w_t n_{st} + d_t - \tau_t, \tag{3}$$

where b_{st} denotes savings in period t, w_t is the real wage, τ_t is the lump-sum tax collected by the government and d_t captures the dividends from the firms. The savings from the previous period earn a gross nominal interest at the rate i_{t-1}. π_t is the change in general price level between periods $t-1$ and t, i.e $\pi_t \equiv p_t/p_{t-1}$. The first-order conditions for savers are:

$$n_{st} : u_{n_s,t} = -u_{c_s,t} w_t, \tag{4}$$

$$b_{st} : u_{c_s,t} z_t = \beta_s \mathbb{E}_t u_{c_s,t+1} z_{t+1} \frac{i_t}{\pi_{t+1}}, \tag{5}$$

where $u_{x,t}$ is the derivative of the period utility function with respect to variable x.

Entrepreneurs Similar to the saver, a typical entrepreneur seeks to maximize her lifetime utility:

$$\mathbb{E}_t \sum_{t=0}^{\infty} \beta_e^t u\left(c_{et}, n_{et}\right) z_t, \tag{6}$$

where

$$u\left(c_{et}, n_{et}\right) = (1-\upsilon)\log\left[c_{et} - \upsilon c_{et-1}\right] - \mu_n \frac{{n_{et}}^{1+\varphi}}{1+\varphi}. \tag{7}$$

c_{et} and n_{et} are the consumption and labor supply, and β_e is the discount factor for the entrepreneur. We follow Iacoviello and Neri (2010) to assume that $\beta_s > \beta_e$. The budget constraint for period t is:

$$c_{et} + \frac{i_{t-1}}{\pi_t} b_{et-1} + I_{ct} + I_{dt} = b_{et} + w_t n_{et} + r_{ct} k_{ct-1} + r_{dt} k_{dt-1} + d_t, \tag{8}$$

where b_{et} is the amount of funds borrowed by the entrepreneur, I_{ct} is the investment in clean capital, I_{dt} is the investment in dirty capital, r_{ct} and r_{dt} are the rental costs of the respective capital inputs. The amount of borrowing is subject to the following collateral constraint:

$$b_{et} \leq \kappa\, \mathbb{E}_t \frac{\pi_{t+1} k_t}{i_t}, \tag{9}$$

where $k_t \equiv \left[\gamma^{1/\zeta} k_{dt}^{1-1/\zeta} + (1-\gamma)^{1/\zeta}\left(A_c k_{ct}\right)^{1-1/\zeta}\right]^{\frac{\zeta}{\zeta-1}}$ is a composite of clean and dirty capital used for production with A_c denoting the productive efficiency of clean capital relative to dirty capital. This is analogous to the framework in Acemoglu et al. (2012). κ is a constant factor which the social planner uses to limit the amount of loans available to the entrepreneur. The evolution of the two types of capital stocks follows:

$$k_{dt} = (1-\delta) k_{dt-1} + \Lambda\left(\frac{I_{dt}}{k_{dt-1}}\right) k_{dt-1}, \tag{10}$$

$$k_{ct} = (1-\delta) k_{ct-1} + \Lambda\left(\frac{I_{ct}}{k_{ct-1}}\right) k_{ct-1}, \tag{11}$$

where δ is the depreciation rate of capital. The adjustment costs of capital, following Jermann (1998), are defined as $\Lambda\left(\frac{I_{dt}}{k_{dt-1}}\right) = \frac{\alpha_1}{1-\zeta^{cost}}\left(\frac{I_{dt}}{k_{dt-1}}\right)^{1-\frac{1}{\zeta^{cost}}} + \alpha_2$ and $\Lambda\left(\frac{I_{ct}}{k_{ct-1}}\right) = \frac{\alpha_1}{1-\zeta^{cost}}\left(\frac{I_{ct}}{k_{ct-1}}\right)^{1-\frac{1}{\zeta^{cost}}} + \alpha_2$. The entrepreneur maximizes Eq. (6) subject to Eqs. (8) to (11).

The first-order conditions for entrepreneurs are:

$$n_{et}: u_{n_e,t}z_t = -u_{c_e,t}z_t w_t, \tag{12}$$

$$b_{et}: \lambda_{bt} - \beta_e \mathbb{E}_t u_{c_e,t+1} z_{t+1} \frac{i_t}{\pi_{t+1}} = -u_{c_e,t}z_t, \tag{13}$$

$$k_{dt}: \begin{array}{l} \frac{\lambda_{et}}{\Lambda'\left(\frac{I_{dt+1}}{k_{dt}}\right)} - \beta_e \mathbb{E}_t \lambda_{et+1}\left[r_{dt+1} + \frac{1-\delta+\Lambda\left(\frac{I_{dt+1}}{k_{dt}}\right)}{\Lambda'\left(\frac{I_{dt+1}}{k_{dt}}\right)} - \frac{I_{dt+1}}{k_{dt}}\right] \\ = \gamma^{1/\zeta}\left(\frac{k_{dt}}{k_t}\right)^{-1/\zeta} \kappa_t \lambda_{bt} \mathbb{E}_t \frac{\pi_{t+1}}{i_t} \end{array}, \tag{14}$$

$$k_{ct}: \begin{array}{l} \frac{\lambda_{et}}{\Lambda'\left(\frac{I_{ct+1}}{k_{ct}}\right)} - \beta_e \mathbb{E}_t \lambda_{et+1}\left[r_{ct+1} + \frac{1-\delta+\Lambda\left(\frac{I_{ct+1}}{k_{ct}}\right)}{\Lambda'\left(\frac{I_{ct+1}}{k_{ct}}\right)} - \frac{I_{ct+1}}{k_{ct}}\right] \\ = (1-\gamma)^{1/\zeta}\left(\frac{A_L k_{ct}}{k_t}\right)^{-1/\zeta} \kappa_t \lambda_{bt} \mathbb{E}_t \frac{\pi_{t+1}}{i_t} \end{array}, \tag{15}$$

where λ_{bt} is the Lagrangian multiplier of the collateral constraint.

Firms We extend the production sector in Annicchiarico and Di Dio (2015) to distinguish between the clean and dirty capitals. A firm producing variety j aims to maximize its profits taking into account costs of production factors, tax τ_{xt} on carbon emission x_{jt}, and the cost of emission abatement $\mathcal{C}_{Ajt}$:

$$\max_{n_{jt},k_{cjt-1},k_{djt-1},v_{jt}} \frac{y_{jt}}{\mathcal{M}_{jt}} - w_t n_{jt} - r_{ct}k_{cjt-1} - r_{dt}k_{djt-1} - \tau_{xt}x_{jt} - \mathcal{C}_{Ajt}$$

where $\mathcal{M}_{jt}$ is the price markup over the marginal cost of production. The production function, the carbon emission, and the abatement cost are respectively given by:

$$\begin{aligned} y_{jt} &= A_t\left[1-\Gamma\left(m_t\right)\right] n_{jt}^{1-\alpha} k_{jt-1}^{\alpha}, \\ x_{jt} &= \left[1-v_{jt}\right] \phi_d k_{djt-1}, \\ \mathcal{C}_{Ajt} &= \phi_1 {v_{jt}}^{\phi_2} k_{djt-1}, \end{aligned}$$

where v_{jt} is the abatement effort. A_t is the total factor productivity common to all firms, $\Gamma(m_t)$ is the damage function of aggregate carbon emission m_t, which is assumed to take the form as follows:

$$\Gamma\left(m_t\right) = \gamma_0 + \gamma_1 m_t + \gamma_2 m_t^2. \tag{16}$$

Note that the emission arises only from dirty capital. The optimality conditions for the firm are:

$$(1-\alpha)\,\frac{y_{jt}}{n_{jt}} = \frac{w_t}{mc_{jt}}, \tag{17}$$

$$\alpha\,\gamma^{1/\zeta}\,\frac{y_{jt}}{k_{jt-1}}\left(\frac{k_{djt-1}}{k_{jt-1}}\right)^{-1/\zeta} = \frac{\tilde{r}_{djt}}{mc_{jt}}, \tag{18}$$

$$\alpha\,(1-\gamma)^{1/\zeta}\,\frac{y_{jt}}{k_{jt-1}}\left(\frac{k_{cjt-1}}{k_{jt-1}}\right)^{-1/\zeta} = \frac{r_{ct}}{mc_{jt}}, \tag{19}$$

$$\tau_{xt}\phi_d = \phi_1\phi_2 v_{jt}^{\phi_2-1}, \tag{20}$$

where $\tilde{r}_{djt} \equiv r_{dt} + \tau_{xt}\phi_d\,[1-v_{jt}] + \phi_1 v_{jt}^{\phi_2}$ is the rental cost of high emission capital, taking into account the cost of abatement. Consistent with conventional New Keynesian literature, we assume that in each period, a $(1-\theta)$ fraction of firms is able to re-optimize prices. The optimal price is such that:

$$\tilde{\pi}_t = \frac{\epsilon}{\epsilon-1}\frac{\sum_{l=0}^{\infty}\theta^l\mathbb{E}_t\mathcal{Q}_{tt+l}\left(\frac{p_t}{p_{t+l}}\right)^{-\epsilon}y_{t+l}mc_{t+l|t}}{\sum_{l=0}^{\infty}\theta^l\mathbb{E}_t\mathcal{Q}_{tt+l}\left(\frac{p_t}{p_{t+l}}\right)^{1-\epsilon}y_{t+l}}, \tag{21}$$

where $\tilde{\pi}_t = \tilde{p}_t/p_t$ is the optimal price relative to the general price level. ϵ is the elasticity of substitution between goods of different varieties. $\mathcal{Q}_{tt+l}$ is the dynamic discount factor. Lastly, the gross inflation rate $\pi_t = p_t/p_{t-1}$ is pinned down by:

$$1 = \theta\pi_t^{\epsilon-1} + (1-\theta)\,\tilde{\pi}_t^{1-\epsilon}. \tag{22}$$

Government The government is assumed to maintain a balanced budget. It purchases goods and collects an emission tax from the entrepreneurs and a lump sum tax from the savers:

$$\omega\tau_{xt}x_t + (1-\omega)\tau_t = g_t. \tag{23}$$

Equilibrium Aggregating the production of all varieties, we obtain the total output

$$y_t = A_t\,[1-\Gamma(m_t)]\,n_t^{1-\alpha}k_{t-1}^{\alpha}s_t^{-1}. \tag{24}$$

where s_t is the price dispersion with the law of motion $s_t = (1-\theta)\,\tilde{\pi}_t^{-\epsilon} + \theta\pi_t^{\epsilon} s_{t-1}$. The market for consumption goods clears when production equals the total demand:

$$\omega\, y_t = \omega\left[c_{et} + I_{ct} + I_{dt} + \phi_1 v_t^{\phi_2} k_{dt-1}\right] + (1-\omega)\, c_{st} + g_t. \tag{25}$$

The loan market clears when savings are equal to borrowings

$$\omega\, b_{et} = (1-\omega)\, b_{st}. \tag{26}$$

At a rate of ξ, the global emission stock decays on its own, but is also accumulated as new emission is produced:

$$m_t = (1-\xi)\, m_{t-1} + x_t + x_t^*, \tag{27}$$

where x_t is the overall emission produced by the firms, and x_t^* is the emission from the rest of the world.

Environmental policy The environmental agency has the option of adopting CC or CT. For the former, the environmental agency levies taxes on emissions at a constant rate τ_x. For the latter, x_{jt} is fixed, i.e. $x_{jt} = x$.

Monetary policy The central bank adopts an SLTR:

$$i_t = {i_{t-1}}^{\rho_i}\left(i\pi_t^{\phi_\pi}\hat{y}_t^{\phi_y}\hat{x}_t^{\phi_x}\hat{\tau}_{xt}^{\phi_{\tau x}}\right)^{1-\rho_i}, \tag{28}$$

where $\hat{y}_t$ is the deviation of aggregate output from its potential level, $\hat{x}_t$ is the change in carbon emission from the previous period, and $\hat{\tau}_{xt}$ is the change in carbon tax.

We will analyze four different policy regimes as follows: (i) CC: The environmental agency adopts CC while the central bank sets $\phi_x = \phi_{\tau_x} = 0$. (ii) CC+SLTR: The environmental agency adopts CC and the central bank cooperates by setting $\phi_x > 0$ and $\phi_{\tau_x} = 0$. (iii) CT: The environmental agency adopts CT while the central bank sets $\phi_x = \phi_{\tau_x} = 0$. (iv) CT+SLTR: The environmental agency adopts CT and the central bank cooperates by setting $\phi_x = 0$ and $\phi_{\tau_x} > 0$. The focus is to compare the welfare and sustainability implications between using environmental policy only and combining environmental and monetary policy.

Exogenous variables The exogenous variables are g_t, A_t, and z_t. In this paper, we consider only the productivity shock A_t. We assume that A_t follows an autoregressive process. g_t and z_t are therefore kept at their respective steady state values.

Table 1: Model parameters

Parameter	Description	Value	Source
β_s	Saver discount factor	0.99	
μ_n	Weight of labor in utility function	19.8413	
φ	Inverse of labor supply elasticity	1	
ϵ	Elasticity of substitution between goods	6	
θ	Fraction of firms with prices unchanged	0.75	
α	Share of composite capital in production function	1/3	
γ_0	Damage function coefficient	1.3950e-3	Annicchiarico and Di Dio (2015)
γ_1	Damage function coefficient	-6.6722e-6	
γ_2	Damage function coefficient	1.4647e-8	
δ	Capital depreciation	0.028	
ϕ_1	Abatement cost function coefficient	0.1850	
ϕ_2	Abatement cost function coefficient	2.8	
ξ	Rate of pollution decay	1-0.9979	
β_e	Entrepreneur discount factor	0.975	Iacoviello and Neri (2010)
υ	Habit persistence	0.85	Ravn et al. (2010)
ζ^{cost}	Elasticity of capital investment rate	0.4	Jermann (1998)
ω	Entrepreneur population share	0.5	Quint and Rabanal (2013)
γ	Dirty capital coefficient in composite capital function	0.5	Papageorgiou et al. (2017)
ζ	Elasticity of substitution between clean and dirty capital	10	Papageorgiou et al. (2017)
ϕ_d	Emissions per unit of dirty capital	0.45/9	Authors' estimate
ρ_A	Persistence of productivity shock	0.8	Authors' choice
σ_A	Standard deviation of productivity shock	0.01	Authors' choice

Parameters The parameter values used for simulations and welfare analysis are reported in Table 1. The first panel reports the parameter values obtained from Annicchiarico and Di Dio (2015) whose model is calibrated to the United States. The additional parameters stemming from our extensions to the benchmark model are reported in the second panel of Table 1.

The steady-state values of key variables in our model follow Annicchiarico and Di Dio (2015). The steady-state government purchases-to-GDP ratio $\frac{\overline{g}}{\overline{y}}$ equals 10.22%. The inflation is equal to zero ($\overline{\pi} = \overline{\tilde{\pi}} = 1$). The total factor productivity $\overline{A}$ equals 1.248. The clean capital productive efficiency A_c equals 1.1. ϕ_d is calibrated to obtain the steady-state pollution stock $\overline{x}$ to equal 0.22. The global emission stock $\overline{m}$ at 743 is also close to the steady state value in Annicchiarico and Di Dio (2015). Finally, α_1 and α_2 are calibrated to obtain zero capital adjustment costs in the steady state. Hence, we have $\alpha_1 = \delta^{\frac{1}{\zeta^{cost}}}$ and $\alpha_2 = \frac{\delta}{1-\zeta^{cost}}$. The model is solved in Dynare 4.6.4.

4 Results

We present two key results from our simulations. First, the SLTR improves welfare for the society. Second, the optimal SLTR is effective in reducing emissions. In other words, the SLTR fulfills the dual mandate of welfare maximization and sustainability.

Welfare analysis The central bank's objective is to maximize the welfare of all agents in the economy by choosing the optimal response coefficients, given the policy regime. The welfare function is defined as:

$$\mathcal{W} = \sum_{t=0}^{\infty} \tilde{\beta}^t \left[(1-\omega)\, u\left(c_{st}, n_{st}\right) + \omega\, u\left(c_{et}, n_{et}\right) \right],$$

where the central bank's discount factor is equal to that of the savers, $\tilde{\beta} = \beta_s$. We conduct grid search to pin down the response coefficients for each policy regime using the ranges of coefficients as follows: (i) CC: $\rho_i \in [0, 0.9]$, $\phi_\pi \in [0, 5]$, $\phi_y \in [0, 3]$; (ii)CC+SLTR: $\rho_i \in [0, 0.9]$, $\phi_\pi \in [0, 5]$, $\phi_y \in [0, 3]$ and $\phi_x \in [0, 20]$; (iii) CT: $\rho_i \in [0, 0.9]$, $\phi_\pi \in [0, 5]$, $\phi_y \in [0, 3]$; (iv) CT+SLTR: $\rho_i \in [0, 0.9]$, $\phi_\pi \in [0, 5]$, $\phi_y \in [0, 3]$ and $\phi_{\tau_x} \in [0, 5]$. Our results are shown in Table 2. The optimal value for ρ_i is always equal to 0 in all cases and thus not presented.

Welfare effects of SLTR The consumption-equivalent welfare gain is calculated as

$$100 \times \left(1 - \exp\left[\frac{\left(\tilde{\beta} - 1\right)\left(\mathcal{W}^{X+SLTR} - \mathcal{W}^{X}\right)}{1 - \upsilon}\right]\right), \quad X \in (CC, CT), \tag{29}$$

which gives the percentage of consumption that an agent is willing to give up in order to change from an environmental policy regime CC or CT to one with the SLTR. Table 2 reports the welfare gain associated with the policy regime switching from CC (CT) to CC+SLTR (CT+SLTR) when the economy faces a 1% productivity shock. In general, social welfare improves with the SLTR implemented. The welfare gains are equal to 0.005 percent of consumption in both scenarios.

These welfare changes, however, are not Pareto improvements. In particular, the savers enjoy higher welfare at the expense of the entrepreneurs. This is because the additional reaction to carbon emission introduces a new source of uncertainty to interest payments of the entrepreneurs. Consumption of entrepreneurs therefore faces higher uncertainty, and hence the welfare is lower. Savers, on the other hand, enjoys higher interest income as the interest rate increases with carbon emission or carbon tax. The savers gain more under CC than CT (0.022 vs 0.018 percent) with the entrepreneurs losing more at the same time.

Consistency with sustainability Other than improving social welfare, an equally important goal of the SLTR is to promote sustainability. To see the role of the SLTR in promoting sustainability, we compare the equilibrium dynamics by switching the value of

Table 2: Welfare gain from SLTR.

	ϕ_π	ϕ_y	ϕ_x	ϕ_{τ_x}	Welfare gain (% consumption)		
					Society	Savers	Entrepreneurs
CC	3.9	3	-	-			
CC+SLTR	4	3	16	-	0.005	0.022	-0.013
CT	3.9	3	-	-			
CT+SLTR	4	3	-	0.3	0.005	0.018	-0.009

ϕ_x or ϕ_{τ_x} between 0 and the optimized value, holding all other parameters the same as in CT/CC+SLTR. The impulse responses to a 1% productivity shock are shown in Figs. 2 and 3.

We find the SLTR useful in reducing carbon emissions under CC. Upon a productivity shock, output increases, leading to lower inflation. These two variables jointly result in a lower nominal interest rate, which stimulates the consumption of both savers and entrepreneurs. Under CC, emissions increase with output. With the SLTR, capital inputs are lower due to the higher financing costs. As a result, output and emissions are both lower compared to the scenario without the SLTR. As for CT+SLTR, emissions are unchanged by design. The lower emission tax implies that the demand for emission permits is reduced.

5 Conclusion

As part of the efforts towards addressing the issue of climate change, Singapore gives more priority to promoting sustainability in economic activity and production processes. Banks, being the key sources of funding driving the economy, play an important role in this sustainability agenda. In this paper, we review the latest initiatives by Singapore's financial sector to promote sustainability. Our survey of existing initiatives finds that MAS has effectively transformed the sustainability initiatives in the financial sector. With incentives that support business and banks to adopt green , The combined volume of green and sustainability-linked loans has more than tripled in the past three years. The increasing volume of such loans is expected to shift the preferences of the manufacturing sector towards environmentally friendly projects.

Motivated by these initiatives from MAS and banks in Singapore, we develop a monetary policy framework where the central bank caters to environmental conditions while setting the interest rate. Our results shows that the SLTR framework enhances social welfare while promoting sustainability. This finding suggests the possibility that the present

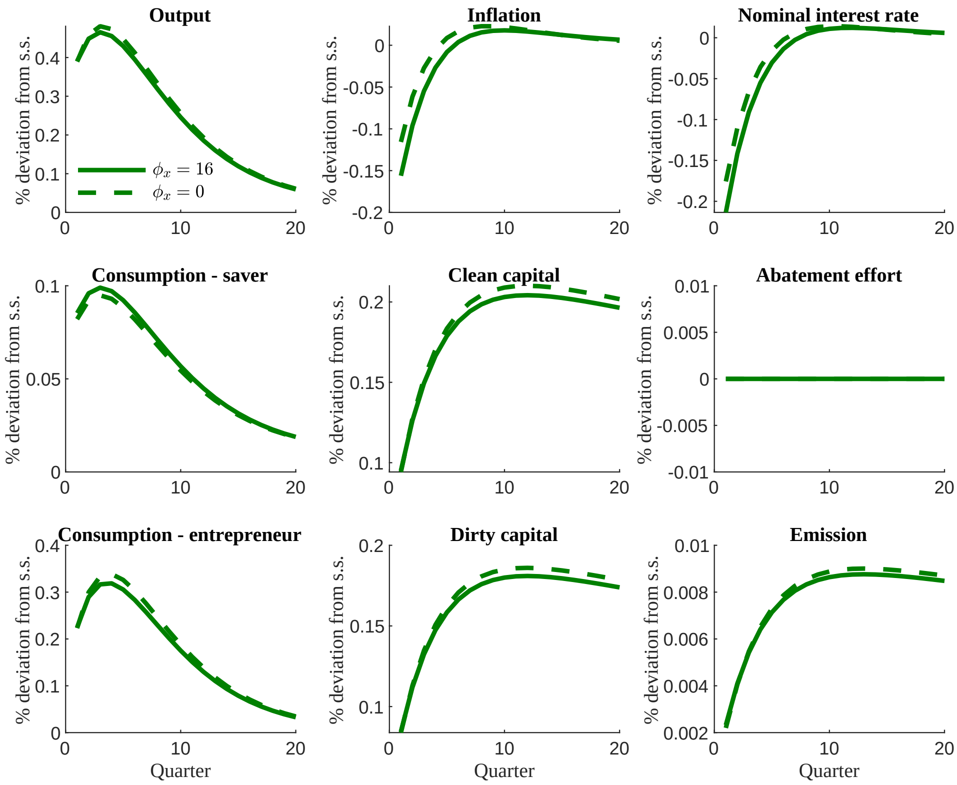

Figure 2: Role of emission gap coefficient ϕ_x in constant carbon tax policy scenario

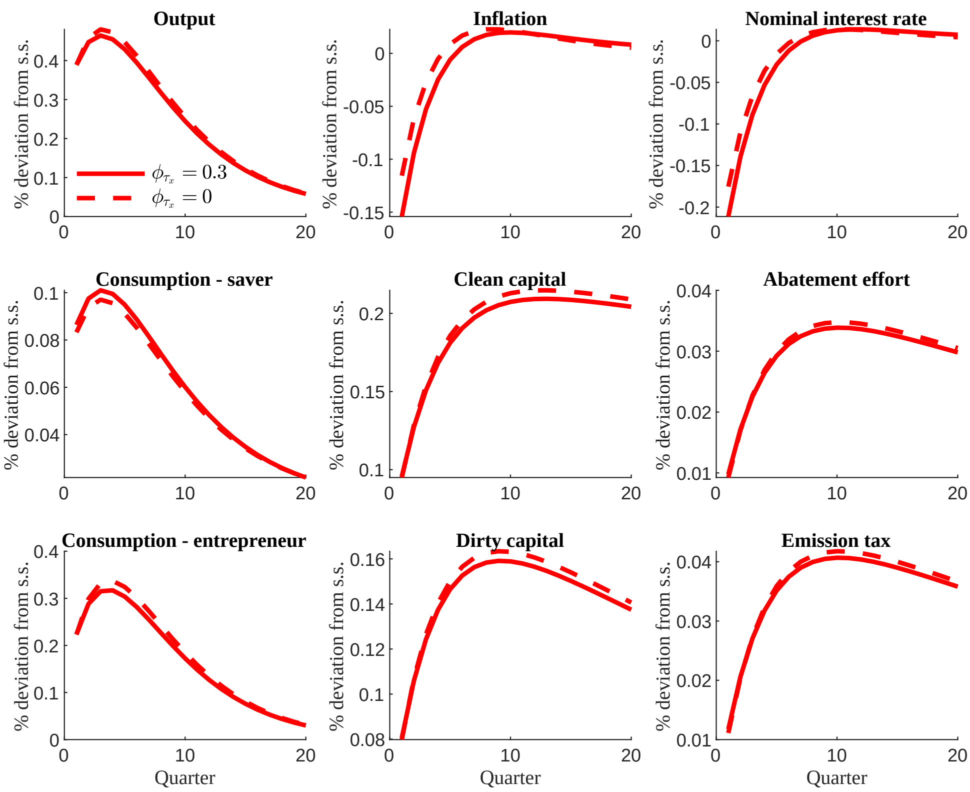

Figure 3: Role of carbon tax inflation coefficient ϕ_{τ_x} in cap and trade policy scenario

approach from MAS to encourage sustainability-linked loans would likely contribute to Singapore's advancement in sustainability agenda.

This research is only a primer of a series of research on the role of the central bank in promoting sustainability. There is room to expand, including having a full-fledged banking sector, or a more detailed production network. We leave these important aspects for future research.

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