RESEARCH PROPOSAL

Title: The Transition to Net Zero in a Small Open Economy

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Motivation and Related Literature:

In recent years, major emitters of greenhouse gases have taken significant steps to begin the process of transitioning away from fossil fuels to achieve net zero emissions by around the middle of the century. In the US, the Inflation Reduction Act (IRA) passed in 2022 has seen an increase in the pace of deployment of renewable energy, a surge in domestic battery manufacturing, and steady growth in electric vehicle adoption. The pace of clean energy deployment is even faster in China, with electric vehicles now accounting for approximately half of light-duty vehicle sales, with the country adding more than the entire US *stock* of solar and wind in just one year.

In this paper, we propose to study the transition to net zero from the perspective of an advanced small open economy like Japan. Advanced open economies in East Asia like Japan represent an important share of global emissions and have seen relatively less progress on decarbonization.

A recent academic literature has emerged to study the economic implications of this energy transition. Bistline, Mehrotra and Wolfram (2023) outlines some of the key energy market and macroeconomic implications of the Inflation Reduction Act for the US, using energy systems modeling.[1] Bistline et al. (2023) investigate the energy market and emissions impacts of IRA using a cross-model comparison of 11 energy systems models; they broadly find substantial acceleration in the pace of emissions reduction from IRA, with US emissions poised to fall 50% relative to peak levels by 2035.

Recent work by Mehrotra (2024) builds on this by studying the energy transition in a closed economy DSGE model. This paper provides a macroeconomic framework for assessing the cost of transitioning to net zero. He finds that the macroeconomic cost of achieving net zero emissions for

[1] Energy systems models are quantitative, industry equilibrium models that are influential in policy design to study the effects of carbon taxes and other energy market policies. Bistline, Mehrotra and Wolfram (2023) used the EPRI REGEN model to project the effect of the IRA on the evolution of electric power generation and EV adoption in the US.

US electric power generation is likely to be very low (less than 0.1 % of steady-state consumption) due to anticipated technological progress in clean energy technologies and the relatively small share of investment in electric power generation. Arkolakis and Walsh (2023) find the price declines in solar panels and lithium-ion batteries are sufficiently large to raise electricity use and increase underlying economic growth, as these technologies become the lowest-cost way of generating electricity in coming decades. It should be noted that this literature on the climate transition is distinct from the earlier literature that has primarily focused on quantifying costs of climate change and macroeconomic damages stemming from increasing temperatures.

The implications of the energy transition from small open economies have been relatively less studied. Airaudo, Pappa and Seoane (2023) represents an early attempt to consider the implications of the green transition from the perspective of a small open economy. In a model calibrated to match the Chilean economy, they find that carbon taxes temporarily raise inflation.[2] Our paper will differ from their work by bringing greater detail in the modeling of energy systems and current/future technology costs and focus on longer term macro effects on the GDP growth, investment, interest rates and exchange rates rather than near term business cycle effects on inflation.[3]

Outline:

In this paper, we propose to study the macroeconomic implications of the energy transition from the perspective of a small open economy like Japan. Japan recently articulated its goal for net zero in 2050 in its 6th Strategic Energy Plan and adopted a set of policies to facilitate the transition in its 2023 GX Decarbonization Power Supply Bill.

Specifically, we seek to answer a set of qualitative and quantitative questions. On the qualitative side, how does the energy transition affect key macroeconomic variables of interest for a small open economy: GDP growth, consumption growth, the interest rate, the exchange rate, and the current account? On the quantitative side, how costly is the transition for a small open economy with two key characteristics: a high degree of reliance on imports for both fossil and clean energy

[2] The IMF studies the energy transition in a global economy model called GMMET. See Carton et al. (2023) for a description.

[3] For instance, Mehrotra (2024) captures the intermittency of solar and wind using a variable elasticity of substitution production function for electricity generation. Solar and wind become less substitutable as they increase as a share of electricity generation.

technologies and a somewhat more limited renewable energy resource potential relative to the US, Europe or China.

The energy transition for small open economies like Japan poses unique challenges relative to decarbonization in other geographies. First, Japan has more limited land resources for the lowest cost renewable energy: utility-scale solar and onshore wind.[4] Second, Japan lacks access to low cost domestically produced natural gas that, in the US, provides a ready complement to intermittent solar and wind. Third, Japan is a relative laggard in the development and deployment of key technologies of decarbonization: solar panels, lithium-ion batteries, and electric vehicles. Lastly, as both a challenge and an opportunity, Japan is a major importer of fossil fuels. The energy transition is an opportunity for Japan to *lower* its reliance on imported fossil fuels but will likely require increased imports of the key capital needed for decarbonization. Our paper seeks to incorporate these elements to qualitatively and quantitatively understanding the macroeconomic implications of the transition.

We will build a real small open economy model with three types of final goods, an open capital account, and traded energy inputs. A representative household will consume a bundle of traded and non-traded goods produced using domestic labor, capital, and energy. For the traded good, there will be a domestically produced traded good and a foreign good, available at a constant world price. Energy will be produced from clean and fossil capital, with fossil energy requiring an imported fossil fuel that is also available at a constant world price.[5] Production of the traded good is assumed to be more energy intensive and energy will have a limited degree of substitutability with non-energy inputs in production. Fossil fuel is needed in fixed proportions for fossil energy production (i.e. Leontif production).

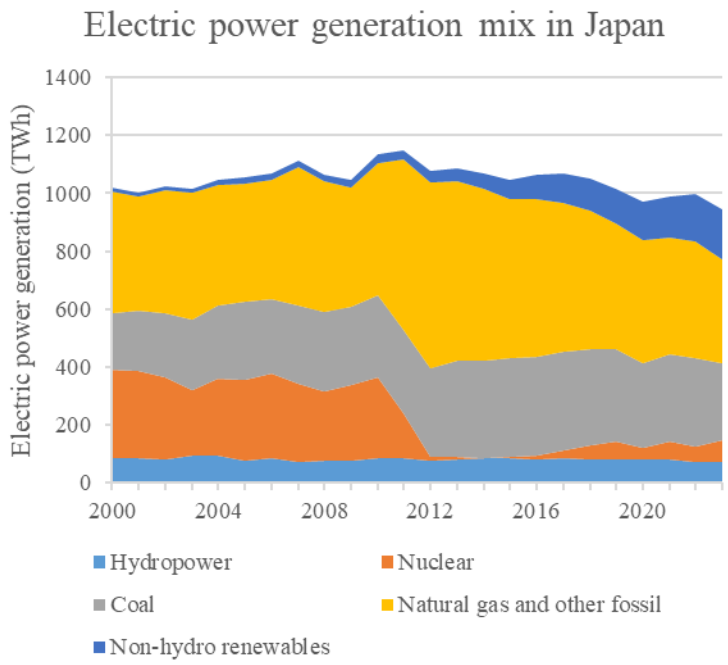
As in Mehrotra (2024), the energy transition will be a policy that requires the substitution away from fossil energy production by some date T in the future. We will analyze both the net zero steady state and the transition path of the economy in response to such a policy that requires the turnover of the energy capital stock from fossil to clean capital. In Mehrotra (2024), we show that such a transition

[4] Theoretically, the offshore wind resource for Japan is plentiful, but both deepwater conditions and earthquake risks make developing offshore wind more challenging in Japan relative to Europe or the Atlantic coast of the US. In any case, offshore wind remains significantly more expensive than either utility-scale solar or onshore wind.

[5] As of 2023, Japan produced just 2% of the natural gas consumed and less than 0.3% of the coal consumed for electricity production.

in a closed economy will generically involve a rise in the investment rate but a *fall* in the real interest rate. The intuition for a fall in the real interest rate is that the economy is substituting away from a cheaper form of energy production and, depending on the speed of the transition, stranding capital. This makes the representative household poorer and lowers consumption growth. We show analytically that a similar mechanism is at work in a small open economy, causing the current account surplus to rise along the transition path and the real exchange rate to depreciate. The new steady state trade balance will be influenced by both interest rate changes due to a diminished net foreign asset position and a reduction in fossil fuel imports.

We will calibrate our model to Japan's economy and quantify the macroeconomic cost of the energy transition. Relative to the findings in Mehrotra (2024), we expect the transition to be more costly simply because carbon-free options for generating electricity in Japan are significantly more expensive than in the US. Nevertheless, with expected technological progress in solar, batteries, and offshore wind, we anticipate that the long-run cost of getting to net zero to be less than 1% of steady state consumption. We will outline how our model can be calibrated to other fossil fuel dependent small open economies like India, Taiwan, South Korea and Vietnam.



Our model will also allow us to characterize the sensitivity of the economy to fossil fuel price shocks. One generic benefit of the energy transition is that energy-dependent importers like Japan will no longer be dependent on volatile fuel imports. Therefore, the economy will be insulated from negative terms-of-trade shocks and the inflationary impact of those shocks. In the quantification of our model, we will seek to measure the macroeconomic benefit from this channel. Importantly, this benefit likely remains even if an economy like Japan remains

dependent on imported clean energy capital. In steady state, the lower economic impact relying on capital imports relative to fuel imports is likely to be a first-order benefit.

Lastly, we anticipate that our model will provide an interesting laboratory for studying the implications of various import-substituting industrial policies. Like the US, Japan is a laggard relative to China in the production of low-cost technologies for the energy transition. To the extent that Japan attempts to erect various barriers to importing solar panels, electric vehicles and batteries, how do those policies impact the transition? We suspect that those policies will both slow the transition and raise the cost, but they may have non-trivial dynamic effects on the exchange rate, interest rate, and current account. Our aim will be to characterize qualitatively the impact of industrial policies and import-substitution on the energy transition. Our model can also be used to assess how Japan could fare in response to a carbon-border adjustment tax (CBAM). Europe is now in the process of implementing such a policy, which penalizes imports that are not subject to a domestic carbon tax. A CBAM is also being considered legislatively in the US.

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