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# The Effects of Policy Mix on the Pollutant Emissions in the United Kingdom[1]

## Introduction

In a broad set of studies, researchers confirmed empirically that the level of pollutant emissions depends on output (see e.g. Annichiarico and Di Dio 2015, Halkos and Paizanos 2015 for review of the literature). In the long run, this phenomenon is known as the environmental Kuznets curve, with pollution growing with GDP at lower levels of development and diminishing for highly-developed countries (see Grossman and Krueger 1993, Atici 2009, Pérez-Suárez and López-Menéndez 2015, Atasoy 2017, Stern 2017, Gill et al. 2018, Liu et al. 2018 for a thorough review of history of the concept, as well as the recent developments).

However, in our recent study (Krajewski and Mackiewicz 2019) we showed empirically that emissions can depend not only on the level of output, but also on the composition of production factors – capital and labour. In an international panel setup, we show that emissions per unit of output may vary for levels of capital intensity and labour intensity of production. It has been widely observed that a stimulating monetary and fiscal policy has a different effect on the share of capital and labour in total output (Buiter 1977). Combining these two mechanisms, we hypothesize that a monetary-fiscal policy mix can exert an impact on emis-

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sions, not only by influencing the overall level of output, but also by affecting the composition of production factors. This means that the effects of the ecological costs of expansionary short-term macroeconomic policy may vary significantly, depending on the policy mix that was used to drive the expansion.

In this article we analyse the impact of policy mix on pollutant emissions in one selected country – the United Kingdom. We motivate this choice by the fact that in a relatively isolated island country the impact of emissions from neighbouring countries is significantly lower than elsewhere. Hence, the effects of macroeconomic policy on the environment may be easier to capture. However, the results for this single case may be also representative for other highly-developed economies.

We perform our analysis using the empirical dynamic stochastic general equilibrium (DSGE) model. The DSGE approach is a standard tool in the analysis of macroeconomic effects of macroeconomic policy (Woodford 2011, Eggertsson 2011, Kara and Sin 2018). The main advantage of DSGE models over alternative approaches is that the results are based on the detailed assumptions concerning the optimizing behaviour of households and firms and are robust to the Lucas (1988) critique. Moreover, the DSGE models, contrary to the panel and time-series econometric approach, not only use the macroeconomic data but also a broad set of information concerning the microeconomic patterns of behaviour of households and firms (Smets and Wouters 2003, Christiano et al. 2018).

The DSGE models have also become a popular method of analysing the links between environmental policies and emissions (Niu et al. 2018). Angelopoulos et al. (2013), Argentiero (2018), Balke and Brown (2018) and Khan et al. (2019) are examples of research that measured the interrelationship between economic policy, business cycles and emissions in the so-called E-DSGE models. This acronym stands for "environmentally-focused DSGE" and means an extension of the standard stochastic business cycle models via an inclusion of environmental variables. The cited authors used these models to examine ecological effects of different environmental and macroeconomic policies. However, to our knowledge, there are no studies available that would focus on the environmental effects of monetary policy and fiscal-monetary policy mix. While this shortage may be surprising, we attribute it to the fact that this channel of impact is by no means obvious. It is typically assumed that monetary policy just influences the level of GDP, with possible further environmental consequences. There is almost no research available that would take into account the possible compositional effects of different monetary-fiscal policy mix on the environment.

We based the analysis on New Keynesian model to explain the impact of shocks on both factors of production (Gali 2008). The assumptions concerning the mechanism of emission are based on Annichiarico and Di Dio (2015). However, we extend their approach by taking into account that capital and labour may differently influence emissions. Moreover, we use detailed assumptions concerning both macroeconomic policy and household and firm behaviour, following the approach of Smets and Wouters (2003). In particular, our model includes

internal habits (Ravn et al. 2006, van den Bijgaart 2018) and a generalised Taylor (1993) rule.

Our research, similarly as most of research on environmental effects of economic policy (e.g. Galinato and Islam 2017, Bekhet et al. 2017, Romano et al. 2017, Skovgaard 2017, Azevedo et al. 2018, Cao et al. 2019), confirms that economic policy significantly affects emissions. The novelty of our research is that we analyse the impact of macroeconomic policy mix on the environment within the business cycle, whereas most studies focus on a long period (e.g. Bernauer and Koubi 2013, Adewuyi 2016, Galinato and Galinato 2016).

In our study we show that fiscal expansionary policy tends to increase labour and decrease capital, whereas the expansionary monetary policy stimulates both production factors to a similar extent. We conclude that there is a significant long-lasting difference between additional stock of pollution that is generated by fiscal and monetary policy. The first one tends to crowd out investments, thus lowering the stock of physical capital. Our empirical analysis shows that, in a highly developed country, a shift from more capital-intensive to more labour-intensive production tends to increase pollution, thus rendering expansionary fiscal policy non-ecological. In contrast, expansionary monetary policy has a pollution-limiting effect. It stimulates the accumulation of physical capital, hence shifting production towards more capital-intensive methods which, in turn, has a positive effect via lowering the emissions per additional unit of GDP. In both cases, the environmental effects of macroeconomic policy are permanent.

## 1. Methods

In this paper, we analyse the impact of the monetary-fiscal mix of stimulating policies on the composition of capital and labour in the production function. Using the E-DSGE model, we show that a short-run economic expansion can have different environmental effects depending on whether it is performed using fiscal or monetary instruments.

We assume the following production function for intermediate goods (Heutel 2012):

$$y_t(i) = (1 - \kappa M_t) A\left(u_{K,t} K_{t-1}(i)\right)^{\alpha} L_t(i)^{1-\alpha} - FC_t, \tag{1}$$

where:

$yt(i)$ – intermediate good of type $i$,
$M_t$ – stock of pollution,
$u_{K,t}K_{t-1}(i)$ – effective capital stock involved to produce intermediate good of type $i$,
$L_t(i)$ – aggregated index of labour used to produce intermediate good of type $i$,
$FC_t$ – fixed costs.

Thus, output of intermediate good depends on three factors:

- stock of pollution,
- effective capital stock,
- labour supply.

The higher the stock of pollution, the lower the production of intermediate goods because of negative impact of pollution on health and human capital. Pollutant emissions accumulate in the environment according to autoregressive process (Annichiarico and Di Dio 2015):

$$M_t = \rho_M M_{t-1} + Z_t, \tag{2}$$

where:
$Z_t$ – pollutant emissions,
$\rho_M \in (0,1)$.

On the one hand, we assume absence of an abatement effort. On the other hand, we take into account that pollutant emissions depend not only on output, but also on the level of each factor of production:

$$z_t(i) = \varpi_y y_t(i) + \varpi_k k_t(i) + \varpi_l l_t(i), \tag{3}$$

where $z_t(i)$ denotes pollutant emissions at firm level and $\varpi_y > 0$.

We do not make any assumptions on the sign of parameters $\varpi_k$ and $\varpi_l$ because, for a given output, it is difficult to predict in advance the direction of impact of capital and labour intensity on pollutant emissions.

While our earlier study (Krajewski and Mackiewicz 2019) provides some guidance in this respect in a panel setup, we have decided to leave these parameters as a subject to estimation. The main reason for this decision was a possibility that this key mechanism may work differently for a single, developed country than for a relatively broad panel of developed and less-developed countries.

We assume that households own a homogenous capital stock. The supply of the rental capital can by changed by changes in the utilisation rate of already installed capital and investing in additional capital. The incomplete or excessive capital utilisation generates additional costs. We assume that it takes one period to install the capital and we take into account that changes in capital involve additional costs (Angeloni et al. 2003).

Household utility depends negatively on labour supply and positively on consumption, relative to external habit (Fuhrer 2000). Households act as price-setters in the labour market. We assume nominal rigidities in the labour market (Bewley 1999, Dickens et al. 2007, Brouillette et al. 2018). In each period, only a part of nominal wages is optimised. According to Calvo (1983) schedule, the probability that in a given period the wage will optimise wages does not depend upon when the household previously set the wage. Thus, wages can only be adjusted if some random signal is received (Erceg et al. 2000, Kollmann 2001).

We assume partial price rigidity (Bils and Klenow 2004, Dhyne et al. 2006, Cavallo 2018). Prices are set according to the Calvo (1983) schedule. The monetary policy follows a generalised Taylor (1993) rule. Fiscal policy affects the economy through shocks in government spending. Spending shocks follow a first-order autoregressive process. The model is closed by the standard equilibrium condition in the goods market.

## 2. Results

We applied Bayesian methodology to estimate most of the parameters of the model. The Bayesian estimation enables us to take into account a priori knowledge about economic phenomena and it is relatively robust to possible model specification errors (Fernández-Villaverde 2010).The parameters of the model were estimated using the data for the United Kingdom over the years 1975–2015, using the quarterly data. This choice has allowed us to ignore within the model the impact of pollutions from other countries, which would not be an optimum choice for any continentally-located country. Moreover, the time series available for the United Kingdom are relatively long.

As commonly applied in DSGE models, calibration was only used in the case of the discount factor and the rate of capital depreciation. The discount factor and the rate of capital depreciation were calibrated on the standard levels widely used in the literature (see eg. Smets and Wouters 2003). We assumed discount factor and the depreciation rate equal to 0.99 and 0.025, respectively.

For the other parameters, we used the procedure of Bayesian estimation. We calculated a posteriori distribution using Metropolis et al. (1953) and Hastings (1970) algorithm (An and Schorfheide 2007).There are four shocks in the model (government spending, interest rate, pollution and productivity shocks). We should thus choose no more than four observable variables for estimation. On the other hand, these four variables should possibly broadly describe both environmental and economic aspects of the economy. Hence, we decided to include the following time series: greenhouse gas emissions from the World Economic Indicators database, output, interest rates and government spending from the European Commission's Eurostat database.

The data covers the period Q1.1975–Q4.2016. In the case of pollution stock, we interpolated quarterly data from the yearly data. All variables, except for interest rate, were transformed into logarithms and then seasonally adjusted using the TRAMO/SEATS. The Hodrick–Prescott filter with the standard smoothing parameter for quarterly data was used to remove the trend. Numerical calculations were performed using the Dynare software package for Matlab. A priori and posteriori distributions of environmental parameters concerning the stock of pollution and pollutant effects on output are shown in Table 1.

**Table 1**

**Prior and posterior distribution of environmental parameters**

| Parameter | Prior mean | Mode | S. d. | t-stat. | Prior | Pst.dev |
|---|---|---|---|---|---|---|
| $\rho_M$ | 0.9080 | 0.82750 | 0.03570 | 23.1841 | beta | 0.0500 |
| $\kappa$ | 0.0001 | 0.00011 | 0.00002 | 0.0002 | invg | 0.1000 |
| $\varpi_y$ | 0.4500 | 0.45000 | 0.10020 | 4.5001 | norm | 0.1000 |
| $\varpi_k$ | 0.0000 | –0.00320 | 0.00570 | 0.5582 | norm | 0.1000 |
| $\varpi_l$ | 0.0000 | 0.10470 | 0.04440 | 2.3574 | norm | 0.1000 |

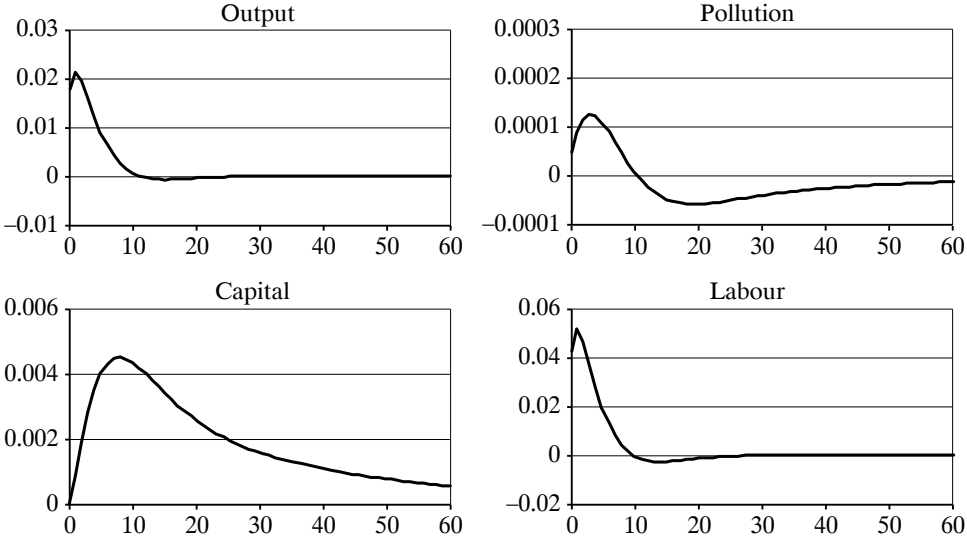
Source: own calculation.

The model with estimated parameters allowed us to analyse the impact of monetary and fiscal policy shocks. The analysis was based on impulse-response functions – the simulations of the effects of one standard deviation of the interest rate and government spending shock, respectively.

The estimates of the parameters show that the impact of each factor of production on pollution is different. In general, the more labour is used for the given output, the higher the pollutant emissions. On the other hand, more capital-intense production tends to decrease the emission of pollutants. Thus, the effect of macroeconomic shocks on pollution stock depends significantly on its impact on the composition of capital and labour. The effects of interest rate and government spending shocks on key variables of the model are shown in Figure 1 and Figure 2.

**Figure 1**

**Impact of a decrease in interest rate by one standard deviation on main macroeconomic variables**

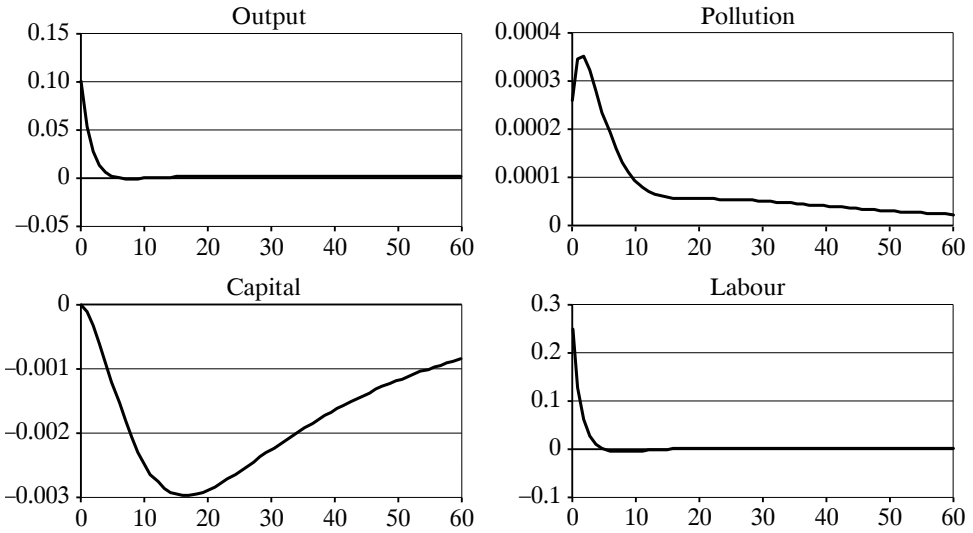



Source: own calculations.

Monetary policy shocks affect economy through the Taylor (1993) rule (Woodford 2001, Caporale et al. 2018). The positive monetary policy shock (lowering the interest rate) results in a higher consumption and investment. Higher investment leads to a significant increase in capital. Moreover, as a consequence of the increase in aggregate demand, the demand for labour grows. However, the increase in labour is relatively lower than the increase in capital, so the monetary shock results in higher capital intensity.

**Figure 2**

**Impact of an increase in government spending by one standard deviation on main macroeconomic variables**




Source: own calculations.

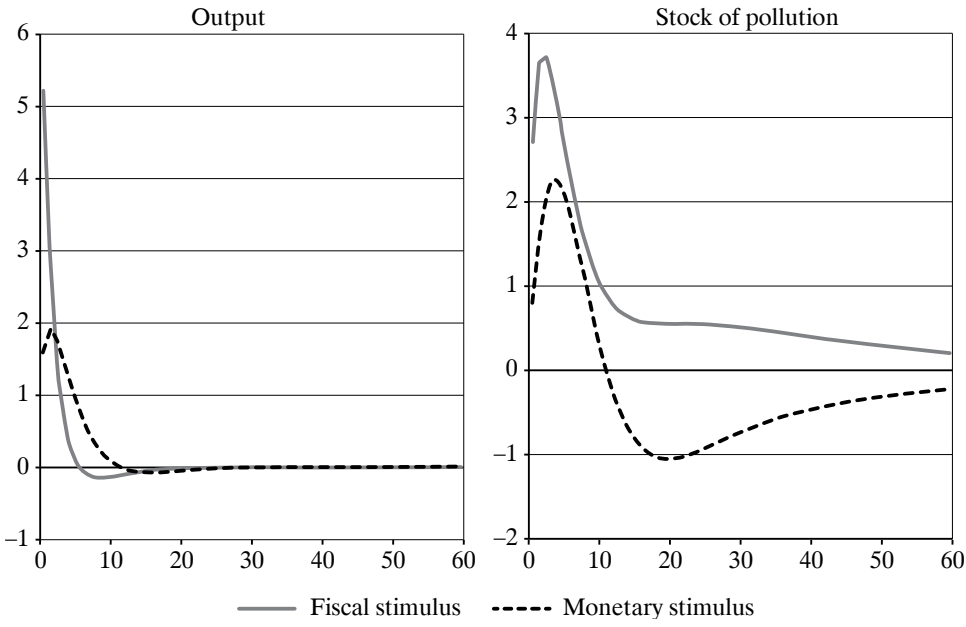
Fiscal policy shock affects both the aggregate demand and supply. According to the negative wealth effect, the government spending shock increases labour supply (Aschauer 1988, Monacelli and Perotti 2008). On the other hand, due to Calvo (1983) mechanism of nominal rigidities, an increase in government spending leads to higher aggregate demand and increase in the demand for labour (Linnemann and Schabert 2003). As a result of a higher aggregate demand, inflation is rising. Due to the Taylor (1993) rule, monetary authorities respond in higher interest rate. Consequently, a well-known "crowding out" effect occurs – investment is crowded out by government spending, which leads to a lower stock of capital.

Thus, the fiscal policy stimulus leads to an increase in labour intensity, whereas the monetary policy stimulus leads to the increase in capital intensity. The estimation results show that an increase in labour leads to much higher pollutant emissions than increase in capital. This means that an expansionary monetary policy entails fewer emissions per unit of output than does expansionary fiscal policy. Hence, in a well-developed country like United Kingdom, an expansionary monetary policy in the short run should be perceived as a relatively environmentally friendly way of boosting economic activity and fighting recessions.

The above simulations are conducted for one standard deviations shocks, as typically assumed in an impulse-response analysis. We also compared the effects for the equivalent fiscal and monetary policy stimulus, which result in the same cumulative increase in output (see Figure 3).

**Figure 3**

**The comparison of the impact of fiscal and monetary stimulus on output and stock of pollution**




Source: own calculations.

The results of this comparative analysis show that fiscal policy has a faster effect on the economy as compared with the impact of monetary policy. However, the impact of fiscal policy also declines faster. The reason for this is that fiscal policy is driven only by the increase in labour, whereas monetary policy stimulus results in higher investments, which leads to a persistent increase in capital. However, in both cases the stimulus generally vanishes after about 12 quarters.

In contrast, fiscal and monetary stimuli have permanent impact on the stock of pollution. This occurs because even transitory changes in output or factors of production have an impact on pollution accumulation in the environment while the pollution stock vanishes very slowly.

Moreover, there is a long-lasting significant difference between additional pollution stock generated by fiscal and monetary policy. From a longer perspective, the fiscal stimulus increases pollutant stock, whereas the monetary stimulus decreases pollutant stock. This happens because an expansionary monetary policy leads to higher capital-intensity of production, which in turn leads to lower pollutant emissions.

## Conclusions

This article analyses the impact of a short-run monetary-fiscal policy mix on the emissions of pollutant in the United Kingdom. Contrary to standard environmental models, we take into account that the emissions depend not only on the level of output, but also on the composition of the factors of production.

We draw on environmentally-focused DSGE models, implemented among others by Annichiarico and Di Dio (2015) and Khan et al. (2019). We extend it by examining the impact of environment through the capital-labour mix channel within the framework of environmentally-focused DSGE.

Our estimates show that the effects of short-run macroeconomic stimulating policy on pollution stock depend significantly on its impact on the composition of capital and labour in GDP. We show that the fiscal policy stimulus leads to an increase in labour and decrease in capital, whereas the expansionary monetary policy stimulates both factors of production to a comparable extent. More capital-intensive production is more environment-friendly, while labour-intensive production turns out to be associated with higher levels of pollutant emission.

Hence, fiscal stimulus increases pollutant stock in the United Kingdom, whereas, what is especially interesting, monetary stimulus tends to decrease the pollutant stock. By lowering interest rates, monetary policy stimulates new investments which, in a well-developed country, are often environment-friendly and lead to lowering the pollution.

In both cases, the effect of stimuli generally vanishes after about 3 years. However, the environmental effects of macroeconomic policy are not transitory as both fiscal and monetary stimulus have a permanent impact on the pollution stock.

It remains open to question, whether this effect is specific to the United Kingdom, or more broadly, to highly developed countries, or is a wider phenomenon. Our earlier panel research that includes less developed countries (Krajewski and Mackiewicz 2019) shows that in the case of a broader group of countries, the results concerning fiscal policy may differ. It should be also noted that during the analysed period a significant structural decarbonisation of the UK economy occurred, which may to some extent interfere the results.

Furthermore, we do not rule out that there may be different channels present through which the monetary-fiscal policy mix may impact upon the environmental burden of expansionary macroeconomic policy. One such channel is related to the composition of additional public expenditures. Public investments may have an offsetting effect on the crowding-out of private investments, hence the overall negative environmental effect may be close to zero. This clearly constitutes a promising and interesting venue for further research.

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## THE EFFECTS OF POLICY MIX ON THE POLLUTANT EMISSIONS IN THE UNITED KINGDOM

### Summary

The article demonstrates the ecological consequences of the fiscal-monetary policy mix that is used to boost economy during the business cycles. This is an important issue especially in the crisis and post-crisis periods, when a new balance between the monetary and fiscal policies is sought after by the governments and central banks. The authors perform their analysis with the empirical environmental dynamic stochastic general equilibrium model, using the quarterly data for the United Kingdom of the period 1975–2016. The results indicate that monetary macroeconomic stimulation is significantly more environment-friendly than fiscal expansion. This is mainly because fiscal expansion tends to crowd out private investment and shift the production from capital-intensive towards more labour-intensive techniques, which results in an increased pollution. Monetary expansion, in turn, has a stimulating effect on the accumulation of the new physical capital, which tends to entail less pollution in a highly developed country like the United Kingdom.

**Keywords:** macroeconomic policy mix, environmental effects, E-DSGE model, United Kingdom

**JEL:** E52, E60, E62, Q50

## WPŁYW POLITYKI BUDŻETOWEJ I PIENIĘŻNEJ NA EMISJĘ ZANIECZYSZCZEŃ W WIELKIEJ BRYTANII

### Streszczenie

Artykuł ukazuje skutki ekologiczne kombinacji polityki budżetowej i pieniężnej stosowanej do pobudzenia gospodarki w trakcie cykli koniunkturalnych. Jest to ważna kwestia zwłaszcza podczas kryzysu i w okresie pokryzysowym, kiedy rządy i banki centralne szukają nowej kombinacji polityki budżetowej i pieniężnej. Autorzy przeprowadzają analizę empiryczną opartą na dynamicznym modelu stochastycznym równowagi ogólnej uwzględniającym efekty środowiskowe (model E-DSGE), na danych kwartalnych dla

Wielkiej Brytanii obejmujących okres od 1975 r. do 2016 r. Wyniki analizy wskazują, że stymulacja pieniężna gospodarki jest bardziej korzystna dla środowiska naturalnego aniżeli ekspansywna polityka fiskalna. Wynika to stąd, że ekspansja fiskalna wypiera na ogół inwestycje prywatne i powoduje przesunięcie produkcji do technik bardziej pracochłonnych, a mniej kapitałochłonnych, co wiąże się ze zwiększoną emisją zanieczyszczeń. Natomiast ekspansja monetarna silnie pobudza akumulację nowego kapitału fizycznego, co oznacza mniejsze zanieczyszczenie środowiska w kraju wysoko rozwiniętym, takim jak Wielka Brytania.

**Słowa kluczowe:** kombinacja polityki budżetowej i pieniężnej, efekty ekologiczne, model E-DSGE, Wielka Brytania

**JEL:** E52, E60, R62, Q50

## ВЛИЯНИЕ БЮДЖЕТНОЙ И ДЕНЕЖНОЙ ПОЛИТИКИ НА ЭМИССИЮ ЗАГРЯЗНЯЮЩИХ ВЕЩЕСТВ В ВЕЛИКОБРИТАНИИ

### Резюме

Статья показывает экологические последствия сочетания бюджетной и денежной политики, применяемой для стимулирования экономики в ходе конъюнктурных циклов. Это важный вопрос, особенно во время кризиса и в период после кризиса, когда правительства и центральные банки ищут новую комбинацию бюджетной и денежной политики. Авторы проводят эмпирический анализ, опирающийся на динамическую стохастическую модель общего равновесия, учитывающую влияние на окружающую среду (модель E-DSGE), на квартальных данных для Великобритании, охватывающих период с 1975 г. до 2016 г. Результаты анализа указывают, что денежное стимулирование экономики является более выгодным для окружающей среды, чем экспансивная фискальная политика. Отсюда следует, что фискальная экспансия вытесняет, как правило, частные инвестиции и вызывает переход к более трудоемким и менее капиталоемким производствам, что влечет за собой увеличение эмиссии загрязняющих веществ. Денежные инструменты в свою очередь сильно стимулируют аккумуляцию нового физического капитала, что означает меньшее загрязнение окружающей среды в такой высокоразвитой стране как Великобритания.

**Ключевые слова:** сочетание бюджетной и денежной политики, экологические последствия, модель DSGE, Великобритания

**JEL:** E52, E60, R62, Q50