An Alternative Reference Scenario for Global CO_2 Emissions from Fuel Consumption: An ARFIMA Approach (*)

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Abstract

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Keywords: Forecasting, reference scenario, CO2emissions, fuel, long memory, ARFIMA.
JEL Codes: C22, C53, O13, Q47, Q54.

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Abstract - In this note, we establish an alternative reference scenario based on an ARFIMA estimated using global CO_2 emissions from 1750 to 2013. These new reference forecasts are free from additional assumptions on demographic and economic variables, often used in most reference forecasts. Instead, we only rely on the properties of the underlying stochastic process for global CO_2 emissions that are, in this sense, closer to fundamentals. Our reference forecasts are clearly below the levels proposed by other reference scenarios available in the literature. This is important, as it suggests that the ongoing policy goals are actually easier to reach than what is implied by the standard reference scenarios. Having lower and more realistic reference emissions projections gives a truer assessment of the policy efforts that are needed, and highlights the lower costs involved in mitigation efforts, thereby maximizing the likelihood of more widespread environmental policy efforts.

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1. Introduction

There is an ongoing debate on how to specify reference case scenarios for CO_2 emissions. This is critical to determine the implied costs and the extent of the policy efforts required to achieve any policy target. In the most basic sense, specifying a reference scenario often means forecasting a path that extrapolates both economic and demographic trends, as well as ongoing emissions policies. Most reference forecasts, however, include alternative economic and demographic assumptions and

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new policy commitments [see, for example, International Energy Agency (2007), OECD (2012), and Energy Information Agency of the US Department of Energy (2013)]. The problem with this approach is that it introduces a great degree of arbitrariness into the forecasts, and thereby clouds the information it intends to provide – the extent of the efforts needed and the corresponding costs.

This note provides reference forecasts based on the statistical fundamentals of the stochastic process that characterizes global CO_2 emissions. As such, these forecasts capture the information included in the sample, and implicitly assume the continuation of any observed trends, thereby providing the most fundamental reference case forecasts.

Our approach is inspired by a budding literature on the analysis of energy and carbon emissions based on a fractional integration approach [see, for example, Elder and Serletis (2008), Lean and Smyth (2009), Gil-Alana et al. (2010), Barassi et al. (2011), Apergis and Tsoumas (2012), Barros et al. (2012), Liu and Chen (2013), and and Gil-Alana et al. (2015)]. The fractional integration approach goes beyond the I(0) stationary/I(1) non-stationary dichotomy to consider the possibility that variables may follow a long memory process, i.e., there may be significant dependence between observations widely separated in time. In this case, the effects of transitory policy shocks may be temporary, but they are long lasting.

2. Data and preliminary results

We use annual data for global CO_2 emissions for the period ranging from 1751 to 2013. Data were obtained from the Carbon Dioxide Information Analysis Centre [Boden at al., 2013]. Global CO_2 emissions are defined as the sum of emissions from burning fossil fuels (solid, liquid, gas and gas flaring) and from cement production. The data do not consider emissions from land use, land-use change, forestry, or international shipping and bunker fuels. All variables are measured in million metric tonnes of carbon per year (Mt, hereafter), and were converted into units of CO_2.

Estimation results for the $\mathrm{ARFIMA}(p, d, q)$ model are presented in Table 1. The best specification was chosen using the Schwartz Bayesian Information Criterion (BIC) and includes two statistically-significant autoregressive terms, of first and second order, and two statistically-significant moving-average terms, of first and seventh order. Furthermore, global CO_2 emissions are fractionally integrated with a statistically-significant degree of persistence of d = 0.354. The confidence intervals for the estimated fractional integration parameters are narrow, in the positive range and are lower than 0.5. This means that, the series is better characterized as 'stationary, but with long memory'. The effects of a one-time random shock in the innovations of these series are thus transitory as the series are mean reverting, but last longer than in the purely-stationary case.

Table 2 summarizes our in-sample forecasting accuracy analysis using the estimated ARFIMA model. For the whole sample period, the mean absolute percentage error is 4.64%, while the adjusted mean absolute percentage error is 5.9%, indicating a good forecast performance. Moreover, only 7.8% of the predicted values lie outside the 95 percent confidence interval. In turn, the U-statistic shows a low level of inequality that suggests that the forecasts compare very well with actual CO_2 emissions. Forecasts are unbiased and have a small variance proportion. Accordingly, most of the forecast error, 95.48%, can be attributed to the unsystematic forecasts error.

3. Global CO_2emissions forecasts until 2100

The forecasts are shown in Figure 1 and Table 3. CO_2 emissions are projected to increase from 36,131 Mt in 2013 to almost 51,883 Mt in 2100. More specifically, the levels of CO_2 emissions in 2030, 2040, 2050, and 2100 are about 27.4%, 34.4%, 39.8%, and 52.9% above 2010 levels.

A significant feature of our forecast is that it suggests a continuous slowdown in the increase in the CO_2emissions. The ARFIMA framework seems to be capture quite competently the shift in the pattern of actual CO_2 emissions that occurred over the last decade on account of more active environmental policies worldwide, as well as the more recent financial and economic crises. Despite this development, unsurprisingly, our reference path does not meet the global CO_2 emission goals designed to assure the stabilization of CO_2 atmospheric concentration at levels consistent with the goal of avoiding the most extreme forms of climate change.

It is important to compare our forecasts with the reference forecasts generally used. To facilitate comparisons, we focus on the projected changes in CO_2 emissions vis-à-vis 2010. International Energy Agency (2007) projects emissions in 2030 and 2050 at 39% and 48 to 55% above the level of 2010 emissions. In turn, the OECD (2012) projects 2030, 2040, 2050 emissions about 32%, 58% and 70% above 2010. Finally, the Energy Information Agency of the US Department of Energy (2013) projects 2030 and 2040 emissions as 33.5% and 42.9% above 2010 levels. This suggests that we clearly project a less pessimistic future evolution of CO_2 emissions. Furthermore, given the slowly declining pattern of marginal changes in CO_2 emissions we project, the difference between our reference case and the existing reference projections increases over time, as we move further and further into the future.

The relevance of our lower reference forecasts becomes apparent when we consider the paths for CO_2 emissions projected under alternative policy scenarios or emission targets. For example, the European Union aims at achieving by 2030 a reduction of CO_2 emissions equivalent to 40% of 1990 emission levels [see, for example, European Commission (2014)]. Translating this goal into a global objective would mean a reduction of about 9 Mt by 2030, compared to the reference scenario. Under our reference scenario, this represents a 25% reduction in emissions, while under other alternative scenarios it is between 32% and 39%. On the other hand, the International Energy Agency (2015) INDC scenario aims at an 8% change in 2030 versus 2013, an increase of about 3 Mt. Under our reference scenario, this would mean allowing for a 30% increase. Other scenarios, such as the International Energy Agency (2015) Scenario 450, assume an actual reduction in emissions, while a bridge scenario postulates seriously curtailing emissions, a less daunting goal under our reference forecast.

4. Conclusions and Policy Implications

Our reference forecast suggests that CO_2 emissions are clearly below the levels suggested by the other reference scenarios available in the literature. This is an important result, as it suggests that the ongoing policy goals are actually within a much closer reach than what is implied by the standard reference scenarios. This is not to say that policy makers should rest on their laurels and relax the ongoing policy efforts to achieve such targets, but rather that whatever efforts are agreed upon will likely be more effective than what is implied by the existing reference forecasts. In other words, the current CO_2 emissions targets can be achieved at a lower cost than what is suggested by such reference forecasts.

A possible reaction to the new reference scenario presented here could be that it is better to err on the side of caution, thus recommending the use of higher projected CO_2 emissions, as suggested by other reference forecasts. However, this situation reflects a delicate trade-off between two competing negotiation strategies. On one hand, having higher emission reference forecasts increases the likelihood of policy action and guarantees that the policies adopted will less likely undershoot the necessary targets. On the other hand, having lower and more realistic reference emissions projections gives a more accurate assessment of the policy efforts that are necessary and of the costs involved, thereby increasing the likelihood of more widespread policy efforts.

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Table 1 –Specification of the ARFIMA model

	Estimates (p-values)	Std. Err.	95% Confidenceinterval	BIC
α_1	0.444 (0.000)	0.110	[0.228 ; 0.629]	
α_2	0.552 (0.000)	*0.109*	[0.339 ; 0.768]	
θ_1	0.742 (0.000)	*0.082*	[0.582 ; 0.903]	*2890.312*
θ_7	0.162 (0.001)	0.020	[0.065 ; 0.260]	
d	0.354 (0.000)	0.046	[0.263 ; 0.444]	

Note: $\hat{\alpha}s$are associated withthe *p*-order termsof the ARcomponent; $\hat{\theta}s$are associated with the*q*-order term of the MA component.

Table 2– In-sample forecasts

	Actual	Forecast	Innovations		95% Confidence interval	
			Level	% of Actual	Lower limit	Upper limit
1900	1,956.6	1,929.4	27.1	1.39	1,544.9	2,313.9
1905	2,429.2	2,352.7	76.5	3.15	1,968.2	2,737.2
1910	3,000.8	2,995.3	5.5	0.18	2,610.8	3,379.8
1915	3,070.4	2,960.4	110.0	3.58	2,575.9	3,344.9
1920	3,414.9	2,847.5	567.4	16.61	2,463.0	3,232.0
1925	3,572.4	3,517.6	54.8	1.53	3,133.2	3,902.1
1930	3,858.2	4,459.8	-601.6	-15.59	4,075.4	4,844.3
1935	3,762.9	3,673.3	89.7	2.38	3,288.8	4,057.7
1940	4,759.5	4,547.1	212.5	4.46	4,162.6	4,931.5
1945	4,250.2	5,002.2	-752.0	-17.69	4,617.8	5,386.7
1950	5,972.3	5,217.3	755.0	12.64	4,832.9	5,601.8
1955	7,481.9	6,990.3	491.6	6.57	6,605.8	7,374.8
1960	9,412.8	9,222.4	190.4	2.02	8,837.9	9,606.8
1965	11,468.3	11,292.0	176.3	1.54	10,907.5	11,676.4
1970	14,850.2	14,395.4	454.8	3.06	14,010.9	14,779.9
1975	16,839.7	17,344.8	-505.1	-3.00	16,960.4	17,729.3
1980	19,474.2	20,352.3	-878.0	-4.51	19,967.8	20,736.7
1985	19,928.5	19,586.5	342.0	1.72	19,202.0	19,971.0
1990	22,449.3	22,629.5	-180.2	-0.80	22,245.0	23,013.9
1995	23,442.3	23,392.2	50.1	0.21	23,007.8	23,776.7
2000	24,787.0	24,254.1	532.9	2.15	23,869.7	24,638.6
2005	29,652.8	29,310.2	342.6	1.16	28,925.8	29,694.7
2010	33,587.9	32,690.4	897.5	2.67	32,305.9	33,074.8
2013	36,131.0	36,169.8	-38.8	-0.11	35,785.3	36,554.3
Mean Absolute Percentage Error					5.90%	
Adjusted Mean Absolute Percentage Error					2.90%	
U Inequality Coefficient					0.0113	
Mean Squared Error decomposition						
Bias proportion					0.0137	
Variance proportion					0.0240	
Covariance proportion					0.9548	

Table 3 –Out-of-sample forecasts for 2014-2100

	Forecasts - f_t	RMSE		95% Confidence interval	
		Mt	**$RMSE_t/f_t$ (%)**	**Lower limit**	**Upper limit**
2015	37,274.1	545.4	1.5	36,377.4	38,174.7
2020	39,545.1	1,258.9	3.2	37,472.6	41,629.2
2025	41,321.5	2,098.3	5.1	37,862.8	44,800.0
2030	42,789.8	2,886.3	6.7	38,026.2	47,579.6
2035	44,044.1	3,628.9	8.2	38,047.1	50,071.3
2040	45,135.6	4,335.5	9.6	37,961.8	52,341.3
2045	46,097.2	5,012.1	10.9	37,793.3	54,432.6
2050	46,949.2	5,663.0	12.1	37,554.7	56,371.8
2055	47,710.5	6,291.1	13.2	37,260.6	58,183.3
2060	48,392.7	6,898.8	14.3	36,918.9	59,882.1
2065	49,004.5	7,487.9	15.3	36,535.1	61,479.5
2070	49,555.3	8,059.7	16.3	36,116.4	62,987.5
2075	50,053.5	8,615.5	17.2	35,670.0	64,417.0
2080	50,499.7	9,156.3	18.1	35,193.5	65,768.9
2085	50,907.6	9,683.0	19.0	34,701.5	67,060.5
2090	51,272.1	10,196.4	19.9	34,185.5	68,285.8
2095	51,595.1	10,697.1	20.7	33,646.1	69,447.4
2100	51,883.3	11,185.7	21.6	33,089.8	70,553.7

Figure 1–Forecasts for 2014-2100