A Simple, Consistent, and More Accurate Measurement and Model of China's GDP Growth

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Preliminary Summary

For years, many have doubted the accuracy of official statistics regarding China's economy, in particular those that measure its GDP growth. We developed a simple, consistent, and more accurate measurement of China's real GDP growth. Unlike typical national GDP accounting, which computes hundreds of compositions, our simple model uses only three variables: (1) energy consumption, (2) CO2 emissions, and (3) international merchandise trade amount.

The reason for this seemingly over-simplified method is twofold: (1) As we suspect the quality of China's GDP numbers, we also suspect many other Chinese official economic variables, on which a traditional and comprehensive method depends. The more data from China we use, the more noises we might get. We assume that these three variables are more objective and reliable due to their straightforward collection and measurement, and they are also more easily observed and compared by international agencies. (2) In contrast to Chen et al. (2019)[1]'s method that tried to dissect detailed local historical data to estimate a more objective Chinese GDP, we want to build a measurement that is usable in near real-time. This will be more relevant and practical for the global community and businesses to understand the state of China's current economy. Therefore, the timing and availability of the model inputs are important.

To estimate the model's coefficients, we use the annual growth rates of these three variables from 2001 to 2019 from ten countries: Australia, Brazil, Canada, Germany, India, Japan, Russia, South Korea, U.K., and U.S. These are among the 13 largest economies in the world, including developed, emerging, and developing countries. The model variables are as follows:

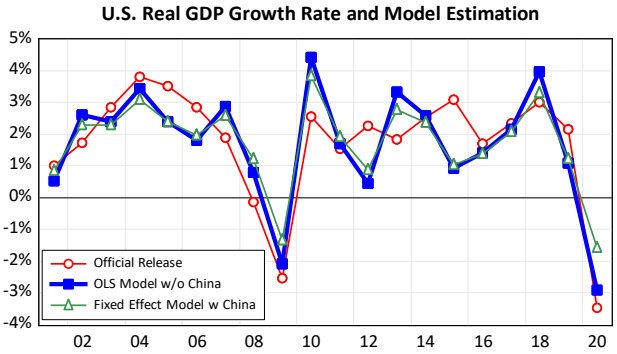
- Dependent Variable: *Real GDP growth rate (rgdpg).* Source: OECD. Note that we focus on annual GDP growth rates rather than GDP level to make sure our time series model is stationary and has less concern over serial correlation problems in the data.
- *Primary energy consumption growth rate (econs).* Sources: Our World in Data and Statistical Review of World Energy by BP. Unit: TWh. We assume that energy consumption is highly related to economic activities.
- *CO2 emissions growth rate (co2g).* Sources: Our World in Data and Carbon Monitor. Unit: tons. There are concerns that there are varying relations between GDP and CO2 growth rates across countries and over time. We tried to incorporate a variable, renewable energy fraction, into the model. However, the results were not ideal, so we do not use it.
- *Nominal merchandise export and import growth rate (eximg).* Source: WITS, US Census, World Bank. Unit: US$. Export growth directly contributes to GDP growth and import growth reflects domestic income and consumption growth. For simplicity, we use nominal growth rather than real term, adjusted

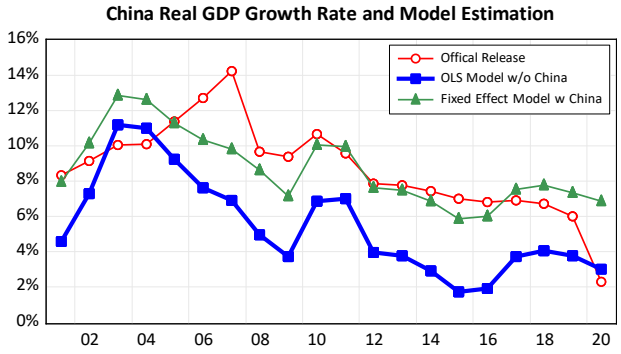
[1] See Wei Chen, Chang-Tai Hsieh, Xilu Chen, and Zheng Song, "A Forensic Examination of China's National Accounts," NBER Working Paper #25754.

for a price deflator. We also tried a variable FDI growth but it is not significant.
The simple OLS model is as follows with adj R-Squared of 0.61:

rgdpg	**=**	**1.91**	**+**	**0.4**	*****	**econg**	**+**	**0.15**	*****	**co2g**	**+**	**0.06**	*****	**eximg**
	(t-stat=15)			***(5.7)***				***(2.9)***				***(3.8)***		

Using this simple model with just three variables, we predict the U.S. real GDP growth rate (blue line in the left chart). Compared to the official number from BEA (red line), our model prediction is impressively good. Using these coefficients from the model, we predict China's GDP growth rate based on three input variables from China. Our estimation (blue line in the right chart) shows that Chinese official numbers are persistently overestimated.



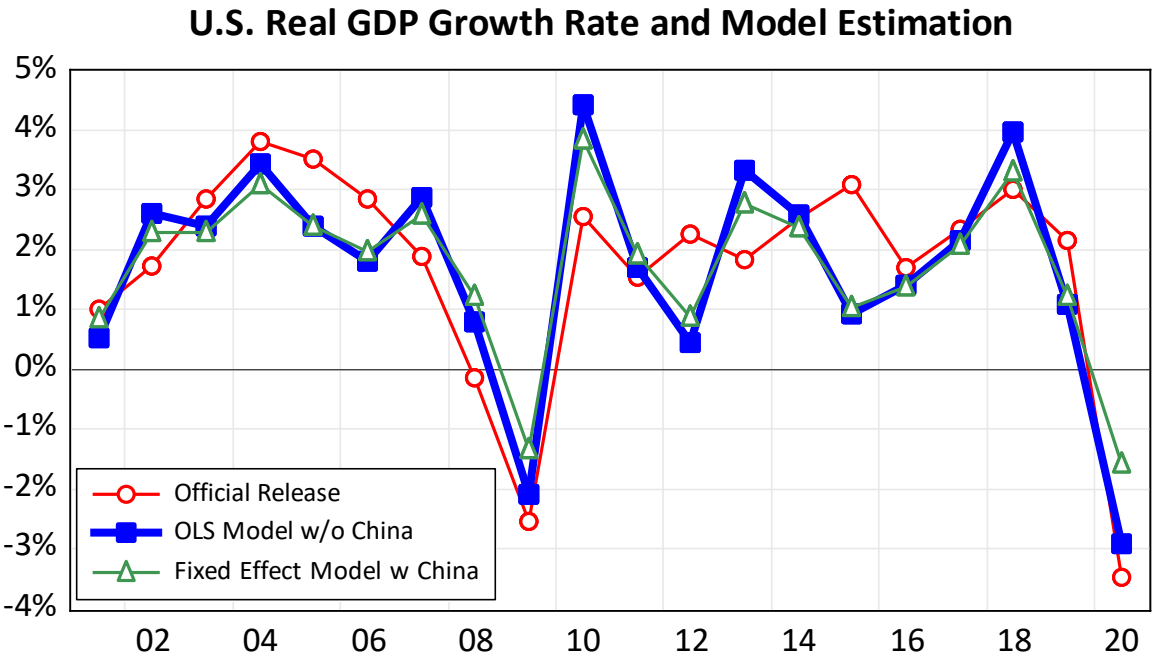


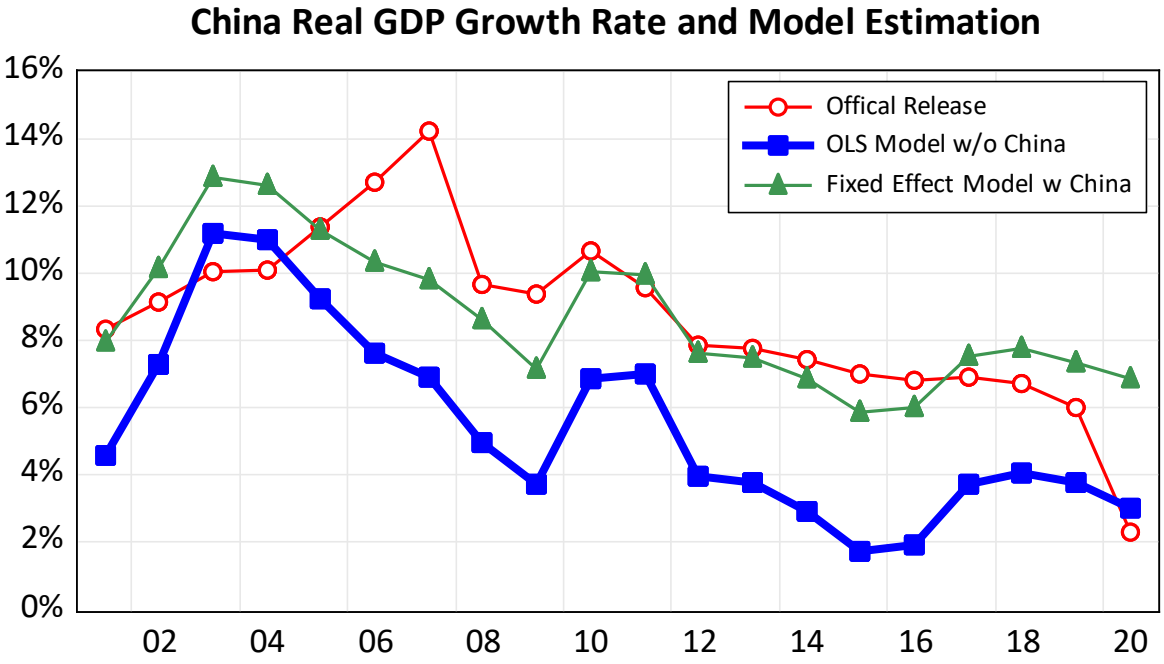
Note that the OLS model assumes there is no distinct characteristic for each country (called fixed effect). When we run the fixed effect model, among these 10 countries only India (+2.2%) and Japan (-1.1%) show significant difference. That is, given the model prediction, India's GDP growth rate is 2.2% greater than the average model prediction. We can either interpret this as a special India factor or simply an over-estimation of India's GDP. If we include China's data in the model, the fixed effect on China would be 4.1%. Similarly, we can either say this is due to China's unique characteristics, or evidence of China's overestimated figures. If we believe it is the former, the model prediction is the green line in the chart. We suggest that the reality should be closer to the blue line rather than the green line.

There is a possibility that the model relationship, such as between CO2 emissions and GDP growth, has changed over time. For example, a global "greener" technology might produce equivalent GDP growth with comparatively less energy consumption and CO2 emissions over time. We test this possibility in the model. We add a time trend variable, and it is insignificant. We try the time fixed effect model, and we don't see particular and significant time varying dynamics on the model either.

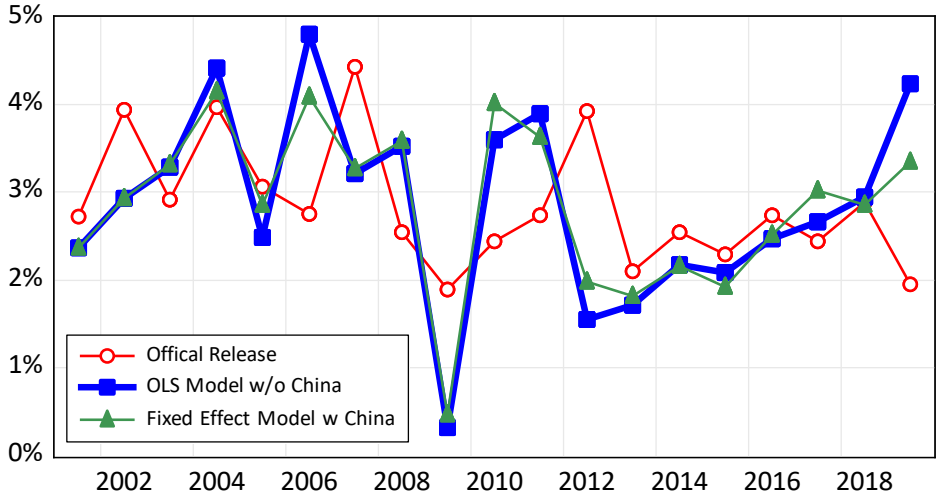
If we look at other variables, e.g. global oil prices, real estate prices in China, credit growth in China, etc., they all indicate there was significant slowdown of the Chinese economy in 2015 and 2016. While we cannot see this from China's official numbers, we do see it in our model estimation. In conclusion, our simple model still has room to improve by incorporating more reliable, consistent, and available data. Nevertheless, this simple three-variable model has provided alternative/more information about China.

Appendix 1. Model Prediction

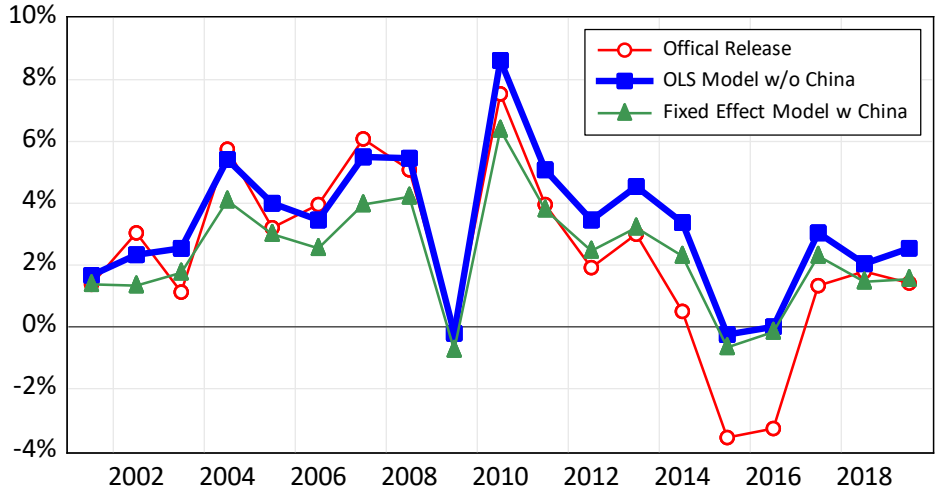




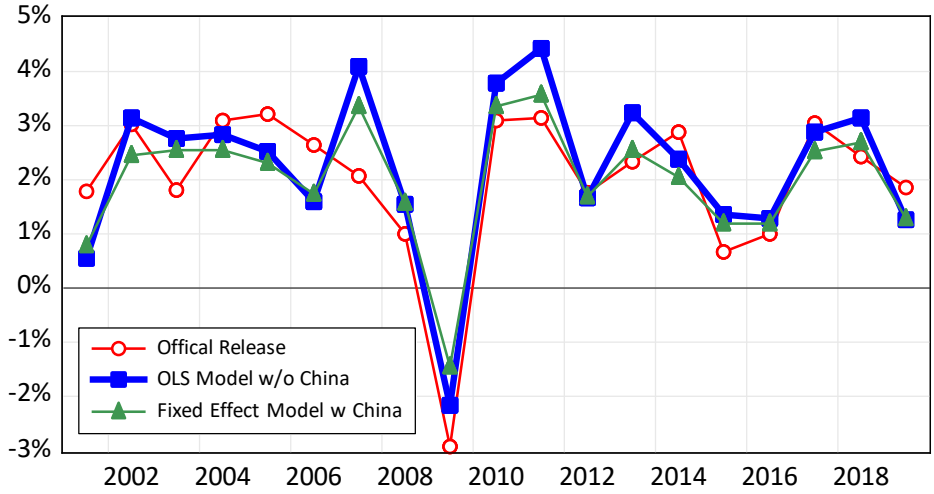
Australia Real GDP Growth Rate and Model Estimation



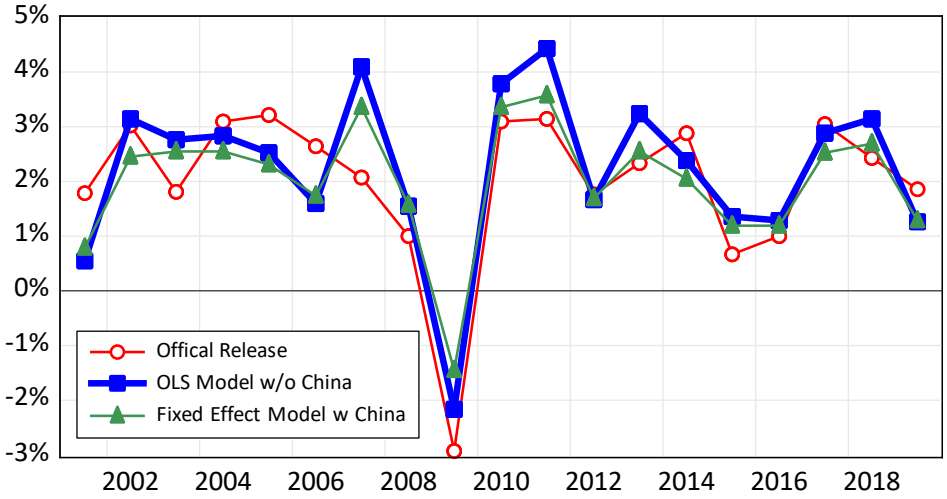
Brazil Real GDP Growth Rate and Model Estimation



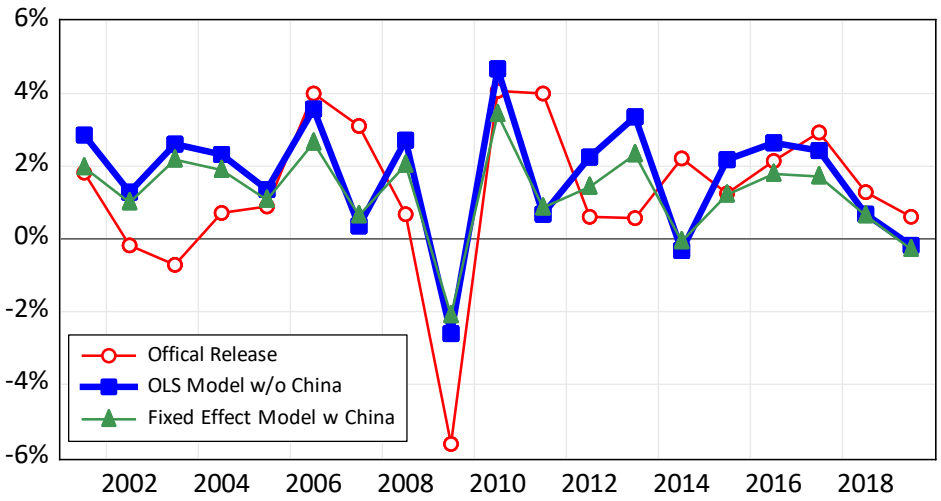
Canada Real GDP Growth Rate and Model Estimation



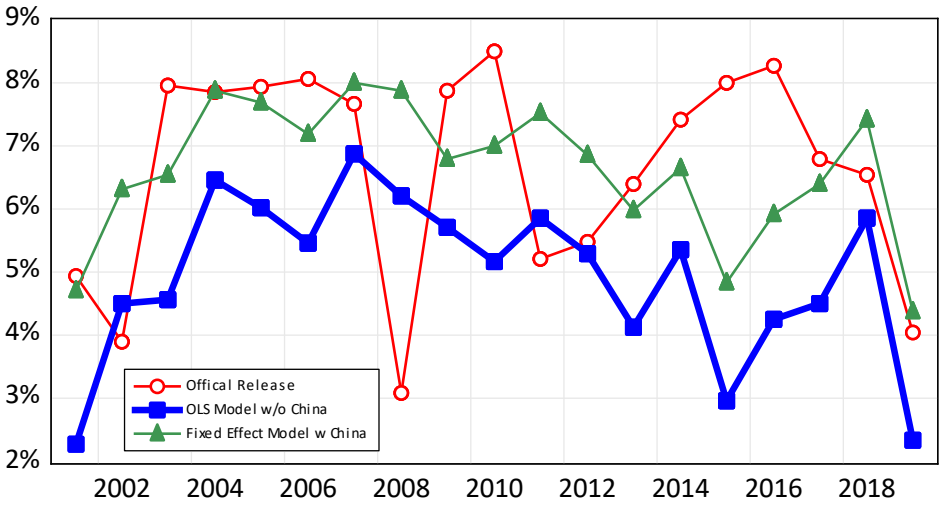
Canada Real GDP Growth Rate and Model Estimation



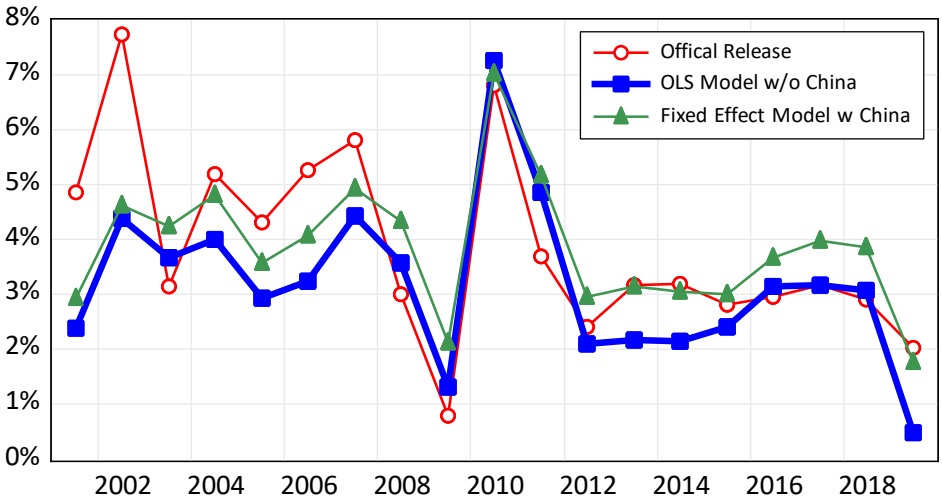
Germany Real GDP Growth Rate and Model Estimation



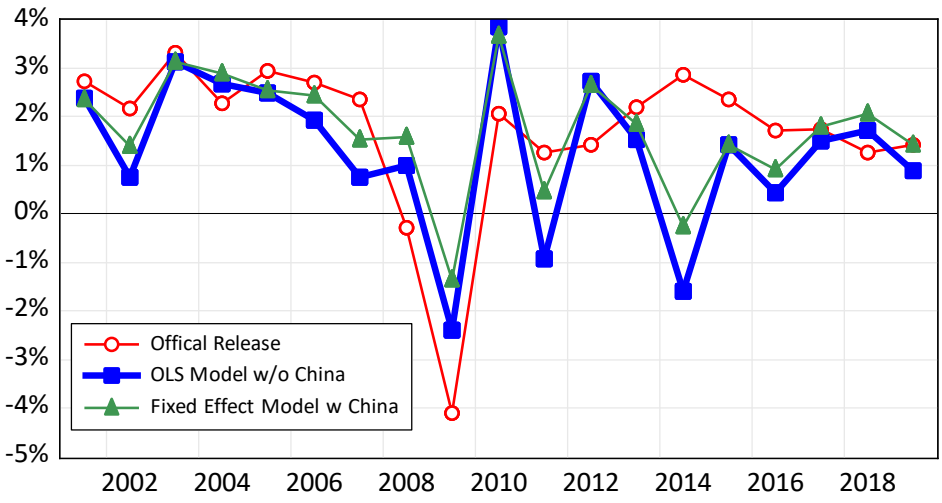
India Real GDP Growth Rate and Model Estimation



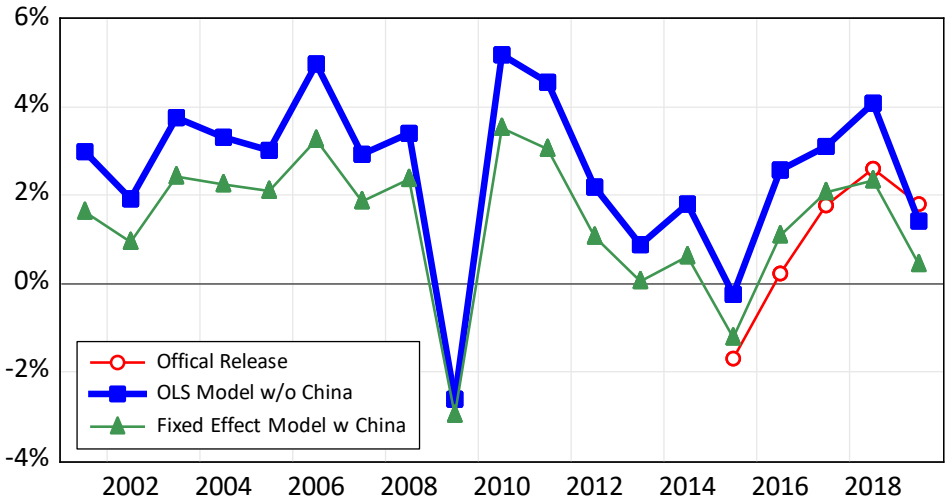
South Korea Real GDP Growth Rate and Model Estimation



U.K. Real GDP Growth Rate and Model Estimation



Russia Real GDP Growth Rate and Model Estimation



Appendix 2. Model Estimation

Dependent Variables: rgdpg -- annual real GDP growth					
Eq1. Benchmark Equation: Pool OLS Model without China					
variable	**estimate**	**std.error**	**t-stat**	**p.value**	
(Intercept)	1.908	0.127	14.999	0.000	
econg	0.377	0.067	5.660	0.000	***
co2g	0.149	0.052	2.898	0.004	***
eximg	0.036	0.009	3.825	0.000	***
Eq2. Pool OLS Model with China					
variable	**estimate**	**std.error**	**t-stat**	**p.value**	
(Intercept)	2.133	0.151	14.118	0.000	***
econg	0.485	0.074	6.560	0.000	***
co2g	0.144	0.060	2.385	0.018	**
eximg	0.026	0.011	2.392	0.018	**
Eq3. Fixed Effect Model without China					
variable	**estimate**	**std.error**	**t-stat**	**p.value**	
(Intercept)	2.086	0.308	6.777	0.000	***
econg	0.240	0.061	3.950	0.000	***
co2g	0.131	0.045	2.931	0.004	***
eximg	0.041	0.008	5.068	0.000	***
Brazil	-0.836	0.424	-1.974	0.050	*
Canada	-0.349	0.424	-0.821	0.413	
Germany	-0.736	0.431	-1.706	0.090	*
India	2.215	0.448	4.942	0.000	***
Japan	-1.142	0.436	-2.620	0.010	**
Russia	-1.292	0.659	-1.961	0.052	*
South Korea	0.777	0.423	1.835	0.068	*
United Kingdom	0.053	0.437	0.122	0.903	
United States	-0.243	0.425	-0.571	0.569	
Eq4. Fixed Effect Model with China					
variable	**estimate**	**std.error**	**t-stat**	**p.value**	
(Intercept)	2.135	0.327	6.534	0.000	***
econg	0.206	0.061	3.393	0.001	***
co2g	0.135	0.046	2.943	0.004	***
eximg	0.041	0.008	4.897	0.000	***
Brazil	-0.818	0.452	-1.810	0.072	*
Canada	-0.380	0.452	-0.840	0.402	
China	4.068	0.480	8.478	0.000	***
Germany	-0.796	0.458	-1.740	0.084	*
India	2.309	0.471	4.901	0.000	***
Japan	-1.218	0.462	-2.638	0.009	***
Russia	-1.317	0.702	-1.875	0.062	*
South Korea	0.794	0.451	1.758	0.080	*
United Kingdom	-0.023	0.462	-0.050	0.960	
United States	-0.302	0.451	-0.669	0.504	

Eq5. Year Fixed Effect Model without China					
variable	**estimate**	**std.error**	**t-stat**	**p.value**	
(Intercept)	2.752	0.519	5.304	0.000	***
econg	0.352	0.071	4.977	0.000	***
co2g	0.150	0.056	2.667	0.008	***
eximg	0.075	0.021	3.551	0.001	***
factor(year)2002	-0.790	0.740	-1.067	0.288	
factor(year)2003	-1.713	0.812	-2.110	0.036	**
factor(year)2004	-1.536	0.879	-1.748	0.082	*
factor(year)2005	-0.956	0.826	-1.157	0.249	
factor(year)2006	-0.714	0.821	-0.870	0.386	
factor(year)2007	-0.805	0.798	-1.009	0.315	
factor(year)2008	-2.793	0.841	-3.322	0.001	***
factor(year)2009	-0.401	0.831	-0.483	0.630	
factor(year)2010	-2.375	0.923	-2.573	0.011	**
factor(year)2011	-1.659	0.867	-1.912	0.058	*
factor(year)2012	-0.840	0.720	-1.167	0.245	
factor(year)2013	-1.002	0.724	-1.385	0.168	
factor(year)2014	0.073	0.726	0.101	0.920	
factor(year)2015	0.199	0.747	0.266	0.790	
factor(year)2016	-0.768	0.702	-1.094	0.276	
factor(year)2017	-1.378	0.789	-1.747	0.083	*
factor(year)2018	-1.557	0.769	-2.024	0.045	**
factor(year)2019	-0.449	0.719	-0.624	0.534	
factor(year)2020	-1.225	1.644	-0.745	0.457	

Eq6. Year Fixed Effect Model with China					
variable	**estimate**	**std.error**	**t-stat**	**p.value**	
(Intercept)	3.067	0.594	5.164	0.000	***
econg	0.443	0.079	5.581	0.000	***
co2g	0.145	0.065	2.232	0.027	**
eximg	0.092	0.025	3.725	0.000	***
factor(year)2002	-1.264	0.850	-1.486	0.139	
factor(year)2003	-2.646	0.935	-2.830	0.005	***
factor(year)2004	-2.646	1.002	-2.640	0.009	***
factor(year)2005	-1.591	0.938	-1.696	0.092	*
factor(year)2006	-1.053	0.935	-1.126	0.262	
factor(year)2007	-0.888	0.916	-0.970	0.334	
factor(year)2008	-2.879	0.955	-3.013	0.003	***
factor(year)2009	0.495	0.956	0.518	0.605	
factor(year)2010	-3.095	1.047	-2.955	0.004	***
factor(year)2011	-2.147	0.986	-2.178	0.031	**
factor(year)2012	-0.842	0.830	-1.014	0.312	
factor(year)2013	-1.101	0.831	-1.325	0.187	
factor(year)2014	0.084	0.834	0.100	0.920	
factor(year)2015	0.538	0.865	0.622	0.534	
factor(year)2016	-0.599	0.810	-0.739	0.461	
factor(year)2017	-1.714	0.897	-1.911	0.058	*
factor(year)2018	-1.937	0.877	-2.209	0.028	**
factor(year)2019	-0.577	0.825	-0.699	0.485	
factor(year)2020	-1.381	1.442	-0.957	0.340	

Eq7. Country and Year Fixed Effect Model with China					
variable	**estimate**	**std.error**	**t-stat**	**p.value**	
(Intercept)	2.626	0.501	5.247	0.000	***
econg	0.198	0.063	3.154	0.002	***
co2g	0.121	0.048	2.519	0.013	**
eximg	0.044	0.018	2.416	0.017	**
Brazil	-0.797	0.405	-1.969	0.051	*
Canada	-0.390	0.411	-0.949	0.344	
Germany	-0.839	0.416	-2.018	0.045	**
India	2.385	0.444	5.373	0.000	***
Japan	-1.250	0.425	-2.942	0.004	***
Russia	-1.377	0.653	-2.109	0.037	**
South Korea	0.812	0.405	2.007	0.047	**
United Kingdom	-0.078	0.428	-0.183	0.855	
United States	-0.229	0.413	-0.555	0.580	
factor(year)2002	-0.270	0.613	-0.441	0.660	
factor(year)2003	-0.892	0.679	-1.314	0.191	
factor(year)2004	-0.314	0.747	-0.420	0.675	
factor(year)2005	-0.100	0.692	-0.145	0.885	
factor(year)2006	0.149	0.688	0.217	0.828	
factor(year)2007	0.090	0.671	0.134	0.893	
factor(year)2008	-1.976	0.703	-2.811	0.006	***
factor(year)2009	-1.596	0.710	-2.247	0.026	**
factor(year)2010	-0.605	0.809	-0.748	0.456	
factor(year)2011	-0.777	0.727	-1.069	0.287	
factor(year)2012	-0.561	0.593	-0.946	0.346	
factor(year)2013	-0.518	0.599	-0.865	0.388	
factor(year)2014	0.216	0.596	0.363	0.717	
factor(year)2015	0.004	0.619	0.006	0.995	
factor(year)2016	-0.520	0.581	-0.895	0.372	
factor(year)2017	-0.516	0.664	-0.778	0.438	
factor(year)2018	-0.696	0.648	-1.075	0.284	
factor(year)2019	-0.309	0.596	-0.518	0.606	
factor(year)2020	-2.656	1.391	-1.910	0.058	*

Eq8. Country and Year Fixed Effect Model with China					
variable	**estimate**	**std.error**	**t-stat**	**p.value**	
(Intercept)	2.602	0.501	5.198	0.000	***
econg	0.159	0.061	2.622	0.010	**
co2g	0.122	0.047	2.584	0.011	**
eximg	0.042	0.018	2.326	0.021	**
Brazil	-0.772	0.421	-1.835	0.068	*
Canada	-0.436	0.426	-1.025	0.307	
China	4.529	0.467	9.689	0.000	***
Germany	-0.920	0.428	-2.148	0.033	**
India	2.519	0.449	5.611	0.000	***
Japan	-1.351	0.436	-3.098	0.002	***
Russia	-1.333	0.676	-1.973	0.050	*
South Korea	0.833	0.420	1.982	0.049	**
United Kingdom	-0.185	0.437	-0.423	0.673	
United States	-0.231	0.424	-0.545	0.587	
factor(year)2002	-0.289	0.603	-0.480	0.632	
factor(year)2003	-0.985	0.674	-1.462	0.146	
factor(year)2004	-0.387	0.733	-0.527	0.599	
factor(year)2005	0.012	0.674	0.018	0.985	
factor(year)2006	0.445	0.671	0.664	0.508	
factor(year)2007	0.592	0.657	0.901	0.369	
factor(year)2008	-1.650	0.681	-2.422	0.017	**
factor(year)2009	-1.372	0.694	-1.978	0.050	**
factor(year)2010	-0.313	0.779	-0.402	0.689	
factor(year)2011	-0.694	0.706	-0.984	0.327	
factor(year)2012	-0.498	0.583	-0.854	0.394	
factor(year)2013	-0.416	0.586	-0.709	0.479	
factor(year)2014	0.209	0.585	0.357	0.722	
factor(year)2015	0.046	0.612	0.076	0.940	
factor(year)2016	-0.433	0.571	-0.759	0.449	
factor(year)2017	-0.510	0.643	-0.793	0.429	
factor(year)2018	-0.692	0.628	-1.101	0.273	
factor(year)2019	-0.429	0.584	-0.735	0.463	
factor(year)2020	-4.156	1.045	-3.977	0.000	***
Eq9. Time Trend Model without China					
variable	**estimate**	**std.error**	**t-stat**	**p.value**	
(Intercept)	56.845	44.013	1.292	0.198	
econg	0.446	0.067	6.650	0.000	***
co2g	0.153	0.054	2.837	0.005	***
time_trend	-0.027	0.022	-1.246	0.215	
Eq10. Time Trend Model with China					
variable	**estimate**	**std.error**	**t-stat**	**p.value**	
(Intercept)	27.390	49.836	0.550	0.583	
econg	0.527	0.073	7.174	0.000	***
co2g	0.153	0.062	2.469	0.014	**
time_trend	-0.013	0.025	-0.505	0.614	