**INTRODUCTION**

In recent years, the climate on Earth has changed markedly: some countries suffer from abnormal heat, others from too harsh and snowy winters, unusual for these places[1]. In addition to global warming, there is also an imbalance of all-natural systems. That leads to a change in the regime of precipitation, temperature anomalies, increasing the frequency of extreme events such as hurricanes, floods, and droughts. Human influence has been the dominant cause of observed warming since the mid-20th century. Continued greenhouse gas emissions will cause further warming and changes in all components of the climate system. Obstructing climate change requires substantial and sustained reductions in greenhouse gas emissions. A solution to climate change could be to reduce greenhouse gas emissions by renouncement of fossil energy sources. The ambitious goal to free the world from fossil fuels implies the broadest use of renewable energy sources[2].

Global progress in the development of renewable energy sources is very significant. The most actively developing areas of renewable energy are solar and wind generation. The spread of innovations in renewable energy is attracting increasing attention as the primary tool to combat climate change and an opportunity to increase the competitiveness of countries in the international market. Thus, the need for an accurate development evaluation tool is clear enough.

According to the BP statistical review of world energy [2], the global trend in wind energy (WE) deployment is quite optimistic (see Picture 1). Nevertheless, the share of WE is not so impressive and represents about 6% of total electricity production (see Picture 1).

*Picture 1. World’s wind energy generation and total electricity production (GWh) [2].*

The International Renewable Energy Agency (IRENA), in its “Future of the Wind” [3], claims about 35% of electricity consumption to be generated from wind by 2050. However, some other prognoses [4][5] are more pessimistic and predict up to 15%, which is still quite ambitious. The forecasting methodology of IRENA [3] has not been described, and Schalk Cloete’s prognosis [4][5] only mentioned S-curves. Thus, there is still a question about wind energy development growth by 2050 and forecasting methodology.

At the same time WE is often recognized as an ecological innovation (EI). “Diffusion of innovations” [10] is one of the main theoretical approaches to understanding how new ideas, products, or services are distributed in various social systems. Many scientists have used the theory for decades. Applying this theory at different levels of analysis allows a better understanding of specific innovation pathways. Simple “Diffusion of innovation” models [6] [7] [8][9] pretend to work well on the macro level.

The great number

The main question of this article is - “Can we obtain meaningful prognosis applying diffusion models to the ecological innovation diffusion process?”

The subject of this article is an analysis of three most popular models applied to the wind energy as one of the most promising renewable technology, which allows check the applicability of those models to evaluate the future trends in renewable energy development.

Thus, the first scope of this article is to check whether the diffusion of innovation models could reproduce the current growth process and whether some models describes the historical dataset better than the others do. The second question is to compare the results of the models with the real process for previous period of five years to see if it`s close enough to say that the model reflects the process good enough at least for a short period ahead.

**1. METHODOLOGY**

*1.1 DATASET.*

The recent statistical review by BP [2] had been used as the dataset. The dataset contains information on total electricity consumption by countries and regions, electricity generation by sources, and installed capacities and production by renewable sources, covering years since 1995 until 2020. Five areas with wind electricity production above 50 TWh per year by 2021 and ten countries were analyzed – World total, Europe, North America, South&Central America, Asia&Pacific regions and Canada, USA, Argentina, Brasil, United Kingdom, Germany, France, Sweden, China and Australia .

*1.2 PRELIMINARY ASSUMPTIONS.*

Three standard models were used to provide the research: The Bass model [6], the Logistic Growth model[11], and the Gompertz model. All models were implied within three modes: the original equation, with variable upper limit and variable upper limit considering the variable costs. Models are initially described by three parameters, two of which determine the function shape, and the last one defines the boundary of process growth. Those parameters are adjusted with the least-squares criteria to minimize the difference between the model and actual data. Thus, the limit of process growth could be evaluated.

Following assumptions were applied to introduce variability into the models:

* Wind energy will take the fixed limited share of the electricity generation.

To introduce this assumption into the models, the following statement accepted:

|  |  |
| --- | --- |
|  | (1) |

*Ew* – wind generation; *t* – time; *k* – the final share of wind energy in total electricity generation; *E* – whole generation for variable upper boundary mode.

* The share depends on wind energy costs.

To introduce this assumption into the models, the following statement accepted:

|  |  |
| --- | --- |
|  | (2)  (3) |

*Ew* – wind generation; *t* – time; *k* – the share of wind energy in total electricity generation depending on wind energy costs; *E* – whole generation for varying upper boundary mode; *R* – constant, *c* – WE costs

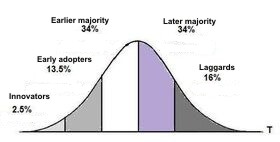
(see Appendix A).

*1.3 MODELS DESCRIPTION.*

***The Logistic Growth model:***

***Description***

In his work “Diffusion of Innovation” [10], Rogers investigated the adoption rates of various innovations. He found that most of the graphs of innovation adoption by members of society resemble a standard bell curve divided into five parts (Pictures 2,3).



**Picture 2. Time distribution of the innovation adopters [10].**



**Picture 3. Total number of adopted innovations [10].**

Total innovation volume represents the typical “S-curve,” which could be described with numerous equations. One of the most known is the “Logistic Growth.”

Basic equation:

|  |  |
| --- | --- |
| Y | (9) |

Where Y(t) – wind generation at period t; Xmin – Wind generation at the first point; M – Upper limit of generation growth since the first known number; l and – coefficients, determining the curve shape.

Variable upper limit:

|  |  |
| --- | --- |
| Y | (10) |

Where *Y(t)* – wind generation at period t; *Xmin* – Wind generation at first point; M(t-1) = the total electricity generation in the previous year; *k* – the achievable wind energy generation share; *l* and – coefficients, determining the curve shape.

Variable upper limit considering variable costs:

|  |  |
| --- | --- |
| Y | (11) |

Where Y(t) – wind generation at period t; Xmin – Wind generation at first point; M(t-1) = the total electricity generation in the previous year, R – the price curve coefficient, ct-1 – costs per 1 KWh during the last year, k, – coefficients, determining the curve shape.

***The Bass model.***

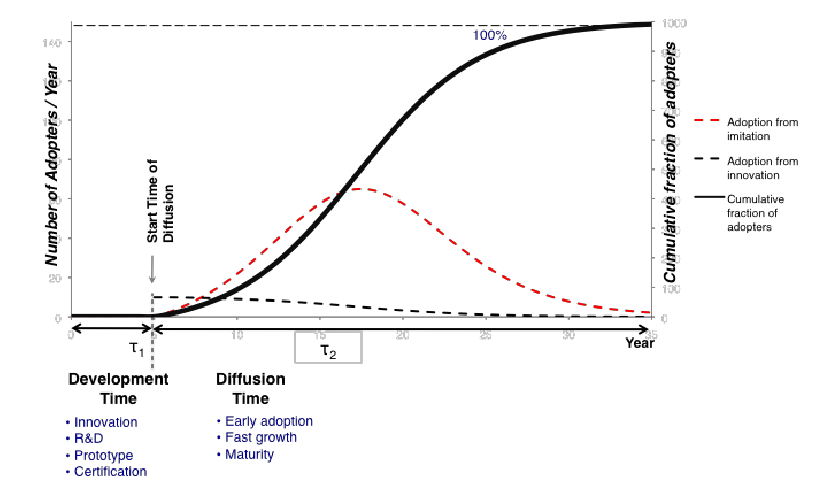
***Description.***

The essence of the Bass model [6] is that two categories explain the growth in the number of consumers of an innovative product:

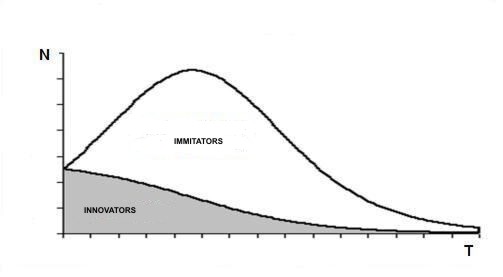
• Those who try a new product themselves in the first place - innovators;

• Those who learn about a new product from the first category - imitators.

At the initial stage of the product life cycle, the innovators prevail. As the number of adopters grows, the effect of imitators increases. The model illustrates well the principles of reinforcing feedback (the number of consumers of a product increases the flow of new consumers due to interpersonal communication). Unlike Rogers, Bass identified not five but only two categories of people (see Picture 4,5).

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**Picture 5. Total number of adopted innovations** [15]**.**



**Picture 4. Time distribution of the innovation adopters** [15]**.**

The Bass Model describes sales at the period, which are the derivative from the distribution. Following original equation [6] had been used.

Basic equation:

|  |  |
| --- | --- |
|  | (6) |

Where S(t) – sales at period t; – cumulative sales through the period [0 ... t - 1]; p – coefficient of innovation, q – coefficient of imitation, m – the total number of all purchasings.

Variable upper limit:

|  |  |
| --- | --- |
|  | (7) |

Where S(t) – sales at period t; – cumulative sales through the period [0 ... t - 1]; p – coefficient of innovation, q – coefficient of imitation, Mi = the total electricity generation in the previous year, k – the share limit of wind energy in the total electricity production.

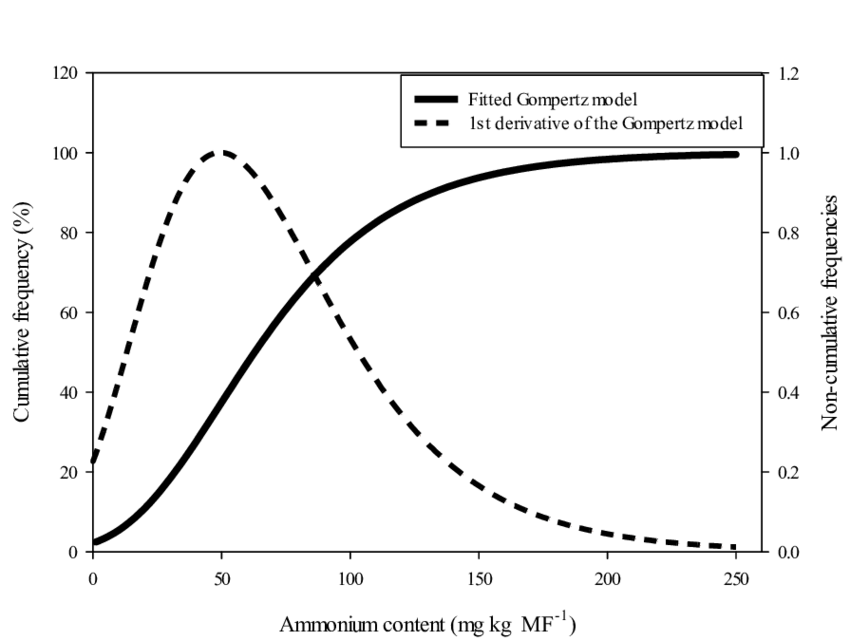
Variable upper limit considering variable costs:

|  |  |
| --- | --- |
|  | (8) |

Where S(t) – sales at period t; – cumulative sales through the period [0 ... t - 1]; p – coefficient of innovation, q – coefficient of imitation, M(t-1) = the total electricity generation in the previous year, R – the price curve coefficient, ct-1 – costs per 1 KWh in the previous year.

***The Gompertz model:***

This is a type of mathematical model for time series where growth is slower at the beginning than at the end of the period (see picture 6,7). It resembles a logistic curve but is not symmetrical. The deceleration does not occur as fast as its acceleration. The Gompertz model [12] [13], successfully applied to different growth processes evaluation [14][15]. In some cases, Gompertz distribution shows better results than logistic growth models.



**Picture 6. Gompertz model and the first derivative example .**

Basic equation:

|  |  |
| --- | --- |
| Y | (12) |

Where Y(t) – wind generation at period t; Xmin – Wind generation at the first point; M – Upper limit of generation growth; l and – coefficients, determining the curve shape.

Variable upper limit:

|  |  |
| --- | --- |
| Y | (13) |

Where *Y(t)* – wind generation at period t; *Xmin* – Wind generation at first point; *M(t)* – the total electricity production in period *t*; *k* – the achievable wind energy generation share; *l* and – coefficients, determining the curve shape.

Variable upper limit considering variable costs:

|  |  |
| --- | --- |
| Y | (14) |

Where Y(t) – wind generation at period t; Xmin – Wind generation at first point; M(t-1) = the total electricity generation in the previous year; R – the price curve coefficient; ct-1 – costs per 1 KWh in the previous year; *l* and – coefficients, determining the curve shape.

1.4 THE RESEARCH STEPS.

The research consists of two steps. In both steps, the equation parameters were evaluated with the OLS criteria using the Gradient Descent optimization method assuming total electricity generation trends and decreasing wind energy LCOE costs. The first step serves to provide the consistency check on the models using data from the 1997-2020 period. Then the regression analysis comparing model and actual values had been provided. The second step is prognosis for the 2016-2020 period consistency check, using 1997-2015 period as a training dataset.

**2. RESULTS**

All models give excellent results describing the full process for different objects (see Appendix B). For most objects, models describe more than 99% of data variation excepting Canada (0.97-0.96), France (0.98), Germany (0.98-0.97), Argentina (0.99-0.88), and Sweden (0.97) where the values are slightly lower (See picture 7). The “worst” p-value is 2.437E-12, which denies any chance to exclude some model from the analysis on this step. In most cases, the choice between models based on its fitness is absolutely equivalent, while the prognosis given by those models could be significantly different. For example, the world trend in positive and negative models by 2050 would be 7392 and 2406 TWh respectively (1591 TWh by the end of 2020).

**Picture 6. The best and the worst models training result.**

The results of success analysis for those models (See Appendix C) are represented in Table 1.

**Table 1. The models consistency check brief results.**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | ***Logistic Model*** | | | ***Bass Model*** | | | ***Gompertz Model*** | | |
| ***Basic equation*** | ***Variable upper limit*** | ***Variable upper limit, variable costs*** | ***Basic equation*** | ***Variable upper limit*** | ***Variable upper limit, variable costs*** | ***Basic equation*** | ***Variable upper limit*** | ***Variable upper limit, variable costs*** |
| **WORLD** | ***SU*** | ***U*** | ***U*** | ***U*** | ***U*** | ***G\**** | ***G*** | ***G*** | ***G*** |
| **EUROPE** | ***U*** | ***G*** | ***G*** | ***G*** | ***G\**** | ***G*** | ***G*** | ***G*** | ***G*** |
| **NORTH AMERICA** | ***SU*** | ***SU*** | ***SU*** | ***G*** | ***G\**** | ***O*** | ***U*** | ***U*** | ***U*** |
| **SOUTH AND C. AMERICA** | ***SO*** | ***SO*** | ***SO*** | ***O\**** | ***SO*** | ***O*** | ***SO*** | ***SO*** | ***SO*** |
| **ASIA PACIFIC** | ***SU*** | ***SU*** | ***SU*** | ***G*** | ***U*** | ***G\**** | ***SU*** | ***SU*** | ***SU*** |
| **CANADA** | ***SO*** | ***SO*** | ***SO*** | ***SO*** | ***SO*** | ***O*** | ***U\**** | ***O*** | ***U*** |
| **USA** | ***SU*** | ***SU*** | ***SU*** | ***G*** | ***G*** | ***G\**** | ***U*** | ***U*** | ***U*** |
| **ARGENTINA** | ***SU*** | ***SU*** | ***SU*** | ***SU*** | ***SU*** | ***SU\**** | ***SU*** | ***SU*** | ***SU*** |
| **BRASIL** | ***SO*** | ***SO*** | ***SO*** | ***G\**** | ***G*** | ***G*** | ***SO*** | ***SO*** | ***G*** |
| **UK** | ***G*** | ***O*** | ***O*** | ***O*** | ***SO*** | ***O*** | ***O*** | ***O*** | ***G\**** |
| **GERMANY** | ***SU*** | ***SU*** | ***U\**** | ***SU*** | ***U*** | ***U*** | ***SU*** | ***SU*** | ***SU*** |
| **FRANCE** | ***SU*** | ***SU*** | ***SU*** | ***O*** | ***SU*** | ***SU*** | ***U*** | ***SU*** | ***G\**** |
| **SWEDEN** | ***SO*** | ***SO*** | ***SO*** | ***G*** | ***SO*** | ***SO*** | ***G\**** | ***SO*** | ***U*** |
| **CHINA** | ***SU*** | ***SU*** | ***SU*** | ***SU*** | ***SU*** | ***SU*** | ***G\**** | ***SU*** | ***G*** |
| **AUSTRALIA** | ***SU*** | ***U*** | ***U*** | ***SU*** | ***SU*** | ***U*** | ***U*** | ***U*** | ***G\**** |

\* – The best model;

SU – Substantial Underestimation (Absolute error and Relational error more than 25%);

U – Underestimation (Absolute error or Relational error between 5% and 25%);

G – Good (Absolute error or Relational error within 5% divergence);

O – Overestimation (Absolute error or Relational error between -5% and -25%);

SO – Substantial Overestimation (Absolute error and Relational error below -25%).

**3. DISCUSSION**

All models could be attuned to completely correspond to the real data (see Appendix E) from 1995 to 2020, which makes the choice of an appropriate model to make evaluations almost impossible. The consistency analyses (see Table 1 and Appendix D) show the adequacy of different models for different regions. Europe has mostly reliable trends, while South America has a mostly optimistic prognosis and North America as well as the World total is mostly underestimated. Nevertheless, we obtained at least two models with high accuracy (the mistake is less than five percent of the target value) for each region. That is quite good predicting ability considering the almost double growth of WE production during the 2015-2020 period.

The consistency check results (see Table 1 and Appendix D) allow the trend analysis (see Table 2 and Appendix E) to pretend to represent the borders for WE development trends. The pessimistic trend is quite a “scary” cause of the diminishing share of WE in total electricity production considering its linear growth (see Appendix B) by 2050, while the optimistic evaluation and averaged trends predict the evolution of WE share.

The mostly interesting is the fact, that all evaluated models perfectly fit the historical data. Thus, we could not evaluate the model applicability on the parameters determination step. The consistency check stage show the Bass model the mostly accurate for most regions within the 5 years period. As for the “long-distance” evaluation, mostly pessimistic prognoses were made with the “Logistic growth” model, while the mostly optimistic trends are represented within the “Gompertz” model.

Another interesting fact is that Bass model shows significant part of “innovators” only for Europe, while other regions are driven by “imitators” only. Considering the moderate growth of electricity generation in Europe and North America during 1995-2020 period, compared to double growth in South America and triple growth in Asia Pacific region we could guess that while Europe provides the progress by replacing the traditional sources within the “green” ones, other regions just try to cover its growing energetic appetite from all the possible sources.

**4. CONCLUSION**

APPENDIX A. WE SHARE LIMIT OF TOTAL ELECTRICITY GENERATION DEPENDING ON COSTS EXAMPLE.

APPENDIX B. MODELS APPROXIMATION RESULTS.

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| ***OBJECT*** | | | | | | | | | | | | |
|  | ***Logistic Model*** | | | | ***Bass Model*** | | | | ***Gompertz Model*** | | | |
| ***Basic equation*** | l | a | | M | p | q | | M | l | a | | M |
| ***Norm. R2*** | | ***p-value*** | | ***Norm. R2*** | | ***p-value*** | | ***Norm. R2*** | | ***p-value*** | |
| ***Variable upper limit*** | l | a | | k | p | q | | k | l | a | | k |
| ***Norm. R2*** | | ***p-value*** | | ***Norm. R2*** | | ***p-value*** | | ***Norm. R2*** | | ***p-value*** | |
| ***Variable upper limit, variable costs*** | k | a | | R | p | q | | R | l | a | | M |
| ***Norm. R2*** | | ***p-value*** | | ***Norm. R2*** | | ***p-value*** | | ***Norm. R2*** | | ***p-value*** | |
| **WORLD** | | | | | | | | | | | | |
|  | **Logistic Model** | | | | **Bass Model** | | | | **Gompertz Model** | | | |
| ***Basic equation*** | 0,241 | 22,714 | | 2460,900 | 0,0005 | 0,249 | | 2407,096 | 2,149 | 0,067 | | 7713,561 |
| ***0,999*** | | ***2,240E-36*** | | ***0,999*** | | ***1,965E-37*** | | ***0,999*** | | ***2,760E-40*** | |
| ***Variable upper limit*** | 0,226 | 21,376 | | 0,083 | 0,0008 | 0,263 | | 0,087 | 2,035 | 0,080 | | 0,163 |
| ***0,999*** | | ***5,511E-37*** | | ***0,999*** | | ***3,990E-38*** | | ***0,999*** | | ***2,224E-38*** | |
| ***Variable upper limit, variable costs*** | 0,209 | 18,823 | | 0,004 | 0 | 0,315 | | 0,005 | 1,814 | 0,092 | | 0,007 |
| ***0,999*** | | ***5,430E-38*** | | ***0,999*** | | ***7,767E-38*** | | ***0,999*** | | ***2,711E-38*** | |
| **EUROPE** | | | | | | | | | | | | |
|  | **Logistic Model** | | | | **Bass Model** | | | | **Gompertz Model** | | | |
| ***Basic equation*** | 0,194 | 22,356 | | 785,143 | 0,0026 | 0,165 | | 968,861 | 1,835 | 0,056 | | 2288,977 |
| ***0,996*** | | ***9,715E-30*** | | ***0,997*** | | ***3,240E-32*** | | ***0,997*** | | ***1,977E-32*** | |
| ***Variable upper limit*** | 0,188 | 22,804 | | 0,203 | 0,0030 | 0,160 | | 0,249 | 1,821 | 0,055 | | 0,584 |
| ***0,996*** | | ***7,751E-30*** | | ***0,997*** | | ***2,216E-32*** | | ***0,997*** | | ***1,329E-31*** | |
| ***Variable upper limit, variable costs*** | 0,162 | 20,443 | | 0,013 | 0,0071 | 0,174 | | 0,016 | 1,587 | 0,058 | | 0,037 |
| ***0,996*** | | ***1,707E-30*** | | ***0,997*** | | ***1,716E-32*** | | ***0,997*** | | ***1,348E-31*** | |
|  | | | | | | | | | | | | |
| **NORTH AMERICA** | | | | | | | | | | | | |
|  | **Logistic Model** | | | | **Bass Model** | | | | **Gompertz Model** | | | |
| ***Basic equation*** | 0,285 | 19,782 | | 459,180 | 0 | 0,271 | | 479,232 | 2,426 | 0,116 | | 705,347 |
| ***0,995*** | | ***2,991E-29*** | | ***0,996*** | | ***2,645E-29*** | | ***0,998*** | | ***2,010E-33*** | |
| ***Variable upper limit*** | 0,286 | 19,558 | | 0,084 | 9,160E-07 | 0,272 | | 0,089 | 2,451 | 0,121 | | 0,123 |
| ***0,995*** | | ***3,896E-29*** | | ***0,996*** | | ***1,908E-29*** | | ***0,997*** | | ***1,322E-32*** | |
| ***Variable upper limit, variable costs*** | 0,287 | 17,386 | | 0,005 | 0 | 0,289 | | 0,006 | 2,495 | 0,152 | | 0,006 |
| ***0,996*** | | ***1,314E-30*** | | ***0,996*** | | ***3,459E-30*** | | ***0,998*** | | ***5,203E-33*** | |
| **SOUTH AND C. AMERICA** | | | | | | | | | | | | |
|  | **Logistic Model** | | | | **Bass Model** | | | | **Gompertz Model** | | | |
| ***Basic equation*** | 0,563 | 21,374 | | 95,828 | 0 | 0,534 | | 93,313 | 5,608 | 0,264 | | 124,514 |
| ***0,998*** | | ***1,822E-34*** | | ***0,996*** | | ***1,268E-29*** | | ***0,998*** | | ***5,898E-33*** | |
| ***Variable upper limit*** | 0,560 | 21,237 | | 0,071 | 0 | 0,532 | | 0,073 | 5,688 | 0,271 | | 0,090 |
| ***0,998*** | | ***1,840E-35*** | | ***0,996*** | | ***1,226E-29*** | | ***0,998*** | | ***5,520E-33*** | |
| ***Variable upper limit, variable costs*** | 0,575 | 20,629 | | 0,004 | 0 | 0,544 | | 0,004 | 6,205 | 0,309 | | 0,005 |
| ***0,998*** | | ***5,760E-36*** | | ***0,995*** | | ***2,280E-28*** | | ***0,998*** | | ***1,5E-32*** | |
| **ASIA PACIFIC** | | | | | | | | | | | | |
|  | **Logistic Model** | | | | **Bass Model** | | | | **Gompertz Model** | | | |
| ***Basic equation*** | 0,301 | 22,655 | | 852,913 | 1,109E-07 | 0,335 | | 774,102 | 2,568 | 0,090 | | 2224,594 |
| ***0,997*** | | ***1,385E-31*** | | ***0,997*** | | ***1,326E-31*** | | ***0,997*** | | ***1,583E-32*** | |
| ***Variable upper limit*** | 0,277 | 20,795 | | 0,058 | 3,633E-05 | 0,342 | | 0,065 | 2,495 | 0,113 | | 0,093 |
| ***0,997*** | | ***4,818E-31*** | | ***0,997*** | | ***2,574E-31*** | | ***0,997*** | | ***4,353E-31*** | |
| ***Variable upper limit, variable costs*** | 0,269 | 18,803 | | 0,003 | 0 | 0,364 | | 0,004 | 2,497 | 0,138 | | 0,004 |
| ***0,997*** | | ***4,983E-31*** | | ***0,997*** | | ***2,097E-31*** | | ***0,997*** | | ***5,105E-31*** | |
| **CANADA** | | | | | | | | | | | | |
|  | **Logistic Model** | | | | **Bass Model** | | | | **Gompertz Model** | | | |
| ***Basic equation*** | 0,381 | 19,337 | | 40,832 | 2,149E-05 | 0,3959 | | 38,301 | 2,489 | 0,112 | | 74,520 |
| ***0,971*** | | ***1,837E-19*** | | ***0,970*** | | ***2,315E-19*** | | ***0,962*** | | ***3,951E-18*** | |
| ***Variable upper limit*** | 0,364 | 19,388 | | 0,063 | 0 | 0,390 | | 0,060 | 2,943 | 0,148 | | 0,091 |
| ***0,971*** | | ***1,917E-19*** | | ***0,972*** | | ***1,248E-19*** | | ***0,966*** | | ***1,176E-18*** | |
| ***Variable upper limit, variable costs*** | 0,353 | 18,062 | | 0,003 | 0 | 0,404 | | 0,004 | 2,532 | 0,147 | | 0,004 |
| ***0,969*** | | ***4,120E-19*** | | ***0,969*** | | ***3,991E-19*** | | ***0,963*** | | ***3,182E-18*** | |
| **USA** | | | | | | | | | | | | |
|  | **Logistic Model** | | | | **Bass Model** | | | | **Gompertz Model** | | | |
| ***Basic equation*** | 0,281 | 19,496 | | 386,042 | 2,144E-05 | 0,269 | | 379,625 | 2,523 | 0,133 | | 491,754 |
| ***0,993*** | | ***4,745E-27*** | | ***0,994*** | | ***2,150E-27*** | | ***0,996*** | | ***1,324E-29*** | |
| ***Variable upper limit*** | 0,285 | 19,267 | | 0,086 | 0 | 0,266 | | 0,092 | 2,442 | 0,124 | | 0,123 |
| ***0,993*** | | ***3,195E-27*** | | ***0,994*** | | ***2,806E-27*** | | ***0,996*** | | ***3,847E-30*** | |
| ***Variable upper limit, variable costs*** | 0,291 | 16,981 | | 0,005 | 6,695E-06 | 0,284 | | 0,006 | 2,013 | 0,111 | | 0,008 |
| ***0,995*** | | ***1,459E-28*** | | ***0,995*** | | ***3,315E-28*** | | ***0,995*** | | ***1,565E-28*** | |
| **ARGENTINA** | | | | | | | | | | | | |
|  | **Logistic Model** | | | | **Bass Model** | | | | **Gompertz Model** | | | |
| ***Basic equation*** | 1,321 | 24,516 | | 14,504 | 1,523E-07 | 0,756 | | 36,170 | 14,181 | 0,573 | | 22,315 |
| ***0,990*** | | ***6,532E-25*** | | ***0,945*** | | ***2,922E-16*** | | ***0,989*** | | ***1,450E-24*** | |
| ***Variable upper limit*** | 1,253 | 24,741 | | 0,117 | 3,014E-06 | 0,667 | | 0,093 | 10,518 | 0,406 | | 0,280 |
| ***0,990*** | | ***5,770E-25*** | | ***0,881*** | | ***2,437E-12*** | | ***0,989*** | | ***1,755E-24*** | |
| ***Variable upper limit, variable costs*** | 1,202 | 24,751 | | 0,008 | 6,308E-06 | 0,622 | | 0,011 | 15,162 | 0,616 | | 0,010 |
| ***0,990*** | | ***7,602E-25*** | | ***0,901*** | | ***2,856E-13*** | | ***0,989*** | | ***1,400E-24*** | |
|  | | | | | | | | | | | | |
| **BRASIL** | | | | | | | | | | | | |
|  | **Logistic Model** | | | | **Bass Model** | | | | **Gompertz Model** | | | |
| ***Basic equation*** | 0,700 | 20,809 | | 60,557 | 3,697-06 | 0,776 | | 57,237 | 8,743 | 0,436 | | 64,736 |
| ***0,998*** | | ***5,390E-35*** | | ***0,998*** | | ***2,858E-33*** | | ***0,996*** | | ***6,284E-30*** | |
| ***Variable upper limit*** | 0,753 | 20,556 | | 0,096 | 7,869E-06 | 0,780 | | 0,094 | 8,712 | 0,437 | | 0,105 |
| ***0,998*** | | ***3,130E-33*** | | ***0,998*** | | ***5,747E-34*** | | ***0,995*** | | ***1,658E-28*** | |
| ***Variable upper limit, variable costs*** | 0,799 | 20,132 | | 0,006 | 6,724E-06 | 0,901 | | 0,006 | 8,757 | 0,449 | | 0,007 |
| ***0,997*** | | ***1,291E-31*** | | ***0,998*** | | ***1,881E-34*** | | ***0,993*** | | ***2,881E-27*** | |
| **UK** | | | | | | | | | | | | |
|  | **Logistic Model** | | | | **Bass Model** | | | | **Gompertz Model** | | | |
| ***Basic equation*** | 0,269 | 22,936 | | 114,409 | 3,547E-06 | 0,264 | | 139,755 | 2,405 | 0,083 | | 292,032 |
| ***0,992*** | | ***4,395E-26*** | | ***0,991*** | | ***2,66E-25*** | | ***0,993*** | | ***3,605E-27*** | |
| ***Variable upper limit*** | 0,279 | 23,329 | | 0,3617 | 0 | 0,270 | | 0,343 | 2,448 | 0,078 | | 1,129 |
| ***0,991*** | | ***1,035E-25*** | | ***0,992*** | | ***3,952E-26*** | | ***0,993*** | | ***7,555E-27*** | |
| ***Variable upper limit, variable costs*** | 0,261 | 22,509 | | 0,0306 | 0 | 0,273 | | 0,034 | 2,542 | 0,106 | | 0,066 |
| ***0,992*** | | ***5,714E-26*** | | ***0,992*** | | ***3,007E-26*** | | ***0,992*** | | ***4,765E-26*** | |
| **GERMANY** | | | | | | | | | | | | |
|  | **Logistic Model** | | | | **Bass Model** | | | | **Gompertz Model** | | | |
| ***Basic equation*** | 0,138 | 33,191 | | 547,182 | 0,002 | 0,129 | | 387,067 | 1,792 | 0,045 | | 900,021 |
| ***0,978*** | | ***6,401E-21*** | | ***0,9778*** | | ***1,056E-20*** | | ***0,975*** | | ***3,812E-20*** | |
| ***Variable upper limit*** | 0,128 | 39,139 | | 1,507 | 0,0018 | 0,115 | | 1 | 1,732 | 0,049 | | 1 |
| ***0,981*** | | ***1,117E-21*** | | ***0,979*** | | ***4,670E-21*** | | ***0,972*** | | ***1,132E-19*** | |
| ***Variable upper limit, variable costs*** | 0,133 | 34,937 | | 48223,036 | 0,003 | 0,116 | | 0,207 | 1,489 | 0,061 | | 0,060 |
| ***0,981*** | | ***1,602E-21*** | | ***0,978*** | | ***8,020E-21*** | | ***0,968*** | | ***4,900E-19*** | |
| **FRANCE** | | | | | | | | | | | | |
|  | **Logistic Model** | | | | **Bass Model** | | | | **Gompertz Model** | | | |
| ***Basic equation*** | 0,220 | 23,983 | | 68,8267 | 0,0008 | 0,187 | | 147,613 | 2,136 | 0,052 | | 394,335 |
| ***0,983*** | | ***2,444E-22*** | | ***0,983*** | | ***2,999E-22*** | | ***0,986*** | | ***4,015E-23*** | |
| ***Variable upper limit*** | 0,219 | 24,049 | | 0,122 | 0,0015 | 0,204 | | 0,147 | 2,116 | 0,065 | | 0,334 |
| ***0,984*** | | ***2,114E-22*** | | ***0,985*** | | ***5,799E-23*** | | ***0,987*** | | ***8,925E-24*** | |
| ***Variable upper limit, variable costs*** | 0,197 | 21,987 | | 0,007 | 0,0037 | 0,212 | | 0,009 | 1,973 | 0,083 | | 0,011 |
| ***0,985*** | | ***9,450E-23*** | | ***0,986*** | | ***3,131E-23*** | | ***0,987*** | | ***1,020E-23*** | |
| **SWEDEN** | | | | | | | | | | | | |
|  | **Logistic Model** | | | | **Bass Model** | | | | **Gompertz Model** | | | |
| ***Basic equation*** | 0,292 | 21,450 | | 32,884 | 6,751E-05 | 0,289 | | 34,532 | 2,435 | 0,086 | | 99,999 |
| ***0,968*** | | ***6,276E-19*** | | ***0,967*** | | ***8,084E-19*** | | ***0,970*** | | ***2,590E-19*** | |
| ***Variable upper limit*** | 0,3015 | 20,582 | | 0,183 | 0 | 0,298 | | 0,203 | 2,665 | 0,122 | | 0,291 |
| ***0,968*** | | ***4,988E-19*** | | ***0,968*** | | ***5,965E-19*** | | ***0,971*** | | ***1,505E-19*** | |
| ***Variable upper limit, variable costs*** | 0,306 | 18,827 | | 0,011 | 0 | 0,306 | | 0,015 | 2,860 | 0,155 | | 0,015 |
| ***0,970*** | | ***2,831E-19*** | | ***0,969*** | | ***4,397E-19*** | | ***0,972*** | | ***1,279E-19*** | |
| **CHINA** | | | | | | | | | | | | |
|  | **Logistic Model** | | | | **Bass Model** | | | | **Gompertz Model** | | | |
| ***Basic equation*** | 0,339 | 22,414 | | 653,670 | 0,0001 | 0,416 | | 573,878 | 2,855 | 0,107 | | 1499,926 |
| ***0,996*** | | ***1,405E-30*** | | ***0,995*** | | ***1,923E-28*** | | ***0,997*** | | ***1,573E-32*** | |
| ***Variable upper limit*** | 0,313 | 20,337 | | 0,0764 | 0,0012 | 0,426 | | 0,0783 | 2,942 | 0,144 | | 0,104 |
| ***0,996*** | | ***5,065E-30*** | | ***0,996*** | | ***1,181E-30*** | | ***0,996*** | | ***3,007E-30*** | |
| ***Variable upper limit, variable costs*** | 0,314 | 18,627 | | 0,004 | 0,0022 | 0,474 | | 0,005 | 1,963 | 0,083 | | 0,010 |
| ***0,996*** | | ***5,202E-30*** | | ***0,997*** | | ***8,567E-31*** | | ***0,994*** | | ***1,079E-27*** | |
|  | | | | | | | | | | | | |
| **AUSTRALIA** | | | | | | | | | | | | |
|  | **Logistic Model** | | | | **Bass Model** | | | | **Gompertz Model** | | | |
| ***Basic equation*** | 0,205 | 25,056 | | 43,433 | 0,0015 | 0,196 | | 50,796 | 2,084 | 0,044 | | 299,993 |
| ***0,990*** | | ***6,109E-25*** | | ***0,991*** | | ***9,069E-26*** | | ***0,992*** | | ***2,336E-26*** | |
| ***Variable upper limit*** | 0,203 | 24,286 | | 0,151 | 0,0018 | 0,186 | | 0,220 | 2,013 | 0,051 | | 0,474 |
| ***0,991*** | | ***1,713E-25*** | | ***0,992*** | | ***3,948E-26*** | | ***0,99343546*** | | ***7,99664E-27*** | |
| ***Variable upper limit, variable costs*** | 0,177 | 22,287 | | 0,009 | 0,0042 | 0,185 | | 0,015 | 1,913 | 0,092 | | 0,011 |
| ***0,992*** | | ***6,894E-26*** | | ***0,992*** | | ***2,056E-26*** | | ***0,992*** | | ***3,785E-26*** | |

APPENDIX C. MODELS CONSISTENCY CHECK RESULTS.

*R. abs.* – Real value in 2020, *M. abs.* – Model prognosis by 2020, *R. rel.* – real growth from 2015 by 2020, *M. rel.* – model growth from 2015 by 2020, ***Err. Abs.*** – result error in percent, *Err. Rel.* – growth error in percent. The positive error value corresponds to underestimation, negative – overestimation.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| ***OBJECT*** | | | | | | | | | |
|  | ***Logistic Model*** | | | ***Bass Model*** | | | ***Gompertz Model*** | | |
| ***Basic equation*** | l | a | M | p | Q | M | l | a | M |
| *R. abs.* | *R. rel.* | ***Err. Abs. (%)*** | *R. abs.* | *R. rel.* | ***Err. Abs. (%)*** | *R. abs.* | *R. rel.* | ***Err. Abs. (%)*** |
| *M. abs.* | *M. rel.* | ***Err. Rel. (%)*** | *M. abs.* | *M. rel.* | ***Err. Rel. (%)*** | *M. abs.* | *M. rel.* | ***Err. Rel. (%)*** |
| ***Variable upper limit*** | l | a | k | p | q | k | l | a | k |
| *R. abs.* | *R. rel.* | ***Err. Abs. (%)*** | *R. abs.* | *R. rel.* | ***Err. Abs. (%)*** | *R. abs.* | *R. rel.* | ***Err. Abs. (%)*** |
| *M. abs.* | *M. rel.* | ***Err. Rel. (%)*** | *M. abs.* | *M. rel.* | ***Err. Rel. (%)*** | *M. abs.* | *M. rel.* | ***Err. Rel. (%)*** |
| ***Variable upper limit, variable costs*** | k | a | R | p | q | R | l | a | M |
| *R. abs.* | *R. rel.* | ***Err. Abs. (%)*** | *R. abs.* | *R. rel.* | ***Err. Abs. (%)*** | *R. abs.* | *R. rel.* | ***Err. Abs. (%)*** |
| *M. abs.* | *M. rel.* | ***Err. Rel. (%)*** | *M. abs.* | *M. rel.* | ***Err. Rel. (%)*** | *M. abs.* | *M. rel.* | ***Err. Rel. (%)*** |
| **WORLD** | | | | | | | | | |
|  | **Logistic Model** | | | **Bass Model** | | | **Gompertz Model** | | |
| ***Basic equation*** | 0,303 | 18,471 | 1328,48 | 0 | 0,302 | 1394,232 | 2,153 | 0,076 | 5439,827 |
| *1591,21* | *759,78* | ***26,14%*** | *1591,21* | *759,78* | ***22,59%*** | *1591,21* | *759,78* | ***5,21%*** |
| *1175,34* | *351,71* | ***53,71%*** | *1231,83* | *402,32* | ***47,05%*** | *1508,28* | *673,16* | ***11,40%*** |
| ***Variable upper limit*** | 0,282 | 17,656 | 0,051 | 0 | 0,308 | 0,0591 | 2,015 | 0,083 | 0,140 |
| *1591,21* | *759,78* | ***21,85%*** | *1591,21* | *759,78* | ***16,55%*** | *1591,21* | *759,78* | ***5,08%*** |
| *1243,58* | *418,85* | ***44,87%*** | *1327,80* | *495,16* | ***34,83%*** | *1510,43* | *675,51* | ***11,09%*** |
| ***Variable upper limit, variable costs*** | 0,258 | 16,027 | 0,003 | 0 | 0,317 | 0,005 | 1,815 | 0,0987 | 0,006 |
| *1591,21* | *759,78* | ***14,72%*** | *1591,21* | *759,78* | ***1,34%*** | *1591,21* | *759,78* | ***3,70%*** |
| *1356,92* | *528,63* | ***30,42%*** | *1569,86* | *733,86* | ***3,41%*** | *1532,38* | *696,44* | ***8,34%*** |
| **EUROPE** | | | | | | | | | |
|  | **Logistic Model** | | | **Bass Model** | | | **Gompertz Model** | | |
| ***Basic equation*** | 0,228 | 18,960 | 544,941 | 0,002 | 0,185 | 797,249 | 1,842 | 0,060 | 2015,765 |
| *510,14* | *191,21* | ***13,93%*** | *510,14* | *191,21* | ***2,07%*** | *510,14* | *191,21* | ***0,98%*** |
| *439,10* | *130,62* | ***31,69%*** | *499,59* | *187,41* | ***1,98%*** | *505,14* | *194,66* | ***-1,81%*** |
| ***Variable upper limit*** | 0,208 | 20,744 | 0,167 | 0,003 | 0,177 | 0,217 | 1,885 | 0,047 | 0,979 |
| *510,14* | *191,21* | ***6,71%*** | *510,14* | *191,21* | ***0,25%*** | *510,14* | *191,21* | ***-4,42%*** |
| *475,93* | *168,55* | ***11,85%*** | *508,84* | *196,49* | ***-2,76%*** | *532,68* | *224,38* | ***-17,35%*** |
| ***Variable upper limit, variable costs*** | 0,176 | 19,236 | 0,012 | 0,005 | 0,161 | 0,025 | 1,881 | 0,047 | 49797,00 |
| *510,14* | *191,21* | ***2,78%*** | *510,14* | *191,21* | ***-6,75%*** | *510,14* | *191,21* | ***-3,94%*** |
| *495,94* | *188,40* | ***1,47%*** | *544,59* | *231,98* | ***-21,32%*** | *530,26* | *222,71* | ***-16,48%*** |
| **NORTH AMERICA** | | | | | | | | | |
|  | **Logistic Model** | | | **Bass Model** | | | **Gompertz Model** | | |
| ***Basic equation*** | 0,423 | 16,142 | 264,565 | 0 | 0,272 | 479,317 | 2,917 | 0,174 | 398,275 |
| *396,73* | *168,37* | ***34,02%*** | *396,73* | *168,37* | ***3,08%*** | *396,73* | *168,37* | ***20,02%*** |
| *261,75* | *37,14* | ***77,94%*** | *384,50* | *147,21* | ***12,57%*** | *317,28* | *88,30* | ***47,56%*** |
| ***Variable upper limit*** | 0,424 | 16,059 | 0,049 | 0 | 0,273 | 0,089 | 2,951 | 0,178 | 0,072 |
| *396,73* | *168,37* | ***33,39%*** | *396,73* | *168,37* | ***2,97%*** | *396,73* | *168,37* | ***19,92%*** |
| *264,26* | *39,16* | ***76,74%*** | *384,93* | *147,93* | ***12,14%*** | *317,70* | *88,33* | ***47,54%*** |
| ***Variable upper limit, variable costs*** | 0,427 | 14,950 | 0,003 | 0 | 0,278 | 0,0071 | 3,081 | 0,213 | 0,004 |
| *396,73* | *168,37* | ***24,90%*** | *396,73* | *168,37* | ***-11,24%*** | *396,73* | *168,37* | ***15,49%*** |
| *297,93* | *71,32* | ***57,64%*** | *441,32* | *203,80* | ***-21,04%*** | *335,27* | *105,06* | ***37,60%*** |
| **SOUTH AND C. AMERICA** | | | | | | | | | |
|  | **Logistic Model** | | | **Bass Model** | | | **Gompertz Model** | | |
| ***Basic equation*** | 0,500 | 26,306 | 756,011 | 3,35E-07 | 0,516 | 130,259 | 3,198 | 0,054 | 114652,9 |
| *85,42* | *53,96* | ***-202,70%*** | *85,42* | *53,96* | ***-18,82%*** | *85,42* | *53,96* | ***-155,94%*** |
| *258,56* | *227,74* | ***-322,07%*** | *101,49* | *73,57* | ***-36,35%*** | *218,62* | *187,95* | ***-248,33%*** |
| ***Variable upper limit*** | 0,471 | 27,858 | 1 | 1,687E-07 | 0,514 | 0,163 | 3,737 | 0,137 | 0,35 |
| *85,42* | *53,96* | ***-223,18%*** | *85,42* | *53,96* | ***-56,79%*** | *85,42* | *53,96* | ***-40,32%*** |
| *276,05* | *245,17* | ***-354,38%*** | *133,93* | *105,51* | ***-95,53%*** | *119,86* | *89,77* | ***-66,37%*** |
| ***Variable upper limit, variable costs*** | 0,485 | 22,938 | 0,01 | 0 | 0,525 | 0,006 | 3,411 | 0,104 | 6253,54 |
| *85,42* | *53,96* | ***-64,22%*** | *85,42* | *53,96* | ***-18,97%*** | *85,42* | *53,96* | ***-69,69%*** |
| *140,27* | *109,62* | ***-103,15%*** | *101,62* | *73,72* | ***-36,62%*** | *144,94* | *114,64* | ***-112,47%*** |
| **ASIA PACIFIC** | | | | | | | | | |
|  | **Logistic Model** | | | **Bass Model** | | | **Gompertz Model** | | |
| ***Basic equation*** | 0,485 | 17,059 | 299,680 | 1,63E-06 | 0,334 | 774,102 | 3,341 | 0,184 | 501,75 |
| *572,64* | *329,58* | ***48,55%*** | *572,64* | *329,58* | ***-0,10%*** | *572,64* | *329,58* | ***33,85%*** |
| *294,59* | *51,76* | ***84,30%*** | *573,24* | *307,11* | ***6,82%*** | *378,83* | *131,69* | ***60,04%*** |
| ***Variable upper limit*** | 0,472 | 15,953 | 0,027 | 0 | 0,354 | 0,049 | 3,507 | 0,223 | 0,035 |
| *572,64* | *329,58* | ***40,49%*** | *572,64* | *329,58* | ***14,28%*** | *572,64* | *329,58* | ***31,00%*** |
| *340,75* | *96,34* | ***70,77%*** | *490,84* | *235,93* | ***28,41%*** | *395,13* | *147,37* | ***55,28%*** |
| ***Variable upper limit, variable costs*** | 0,485 | 14,967 | 0,0018 | 0 | 0,361 | 0,004 | 3,777 | 0,266 | 0,002 |
| *572,64* | *329,58* | ***32,17%*** | *572,64* | *329,58* | ***-1,78%*** | *572,64* | *329,58* | ***25,70%*** |
| *388,39* | *142,25* | ***56,84%*** | *582,85* | *326,84* | ***0,83%*** | *425,45* | *176,58* | ***46,42%*** |
| **CANADA** | | | | | | | | | |
|  | **Logistic Model** | | | **Bass Model** | | | **Gompertz Model** | | |
| ***Basic equation*** | 0,257 | 44,261 | 11843,055 | 0,00015 | 0,338 | 68,261 | 2,376 | 0,0984 | 84,87 |
| *36,10* | *9,14* | ***-130,36%*** | *36,10* | *9,14* | ***-39,48%*** | *36,10* | *9,14* | ***6,09%*** |
| *83,17* | *60,01* | ***-556,85%*** | *50,36* | *27,39* | ***-199,84%*** | *33,90* | *14,98* | ***-63,98%*** |
| ***Variable upper limit*** | 0,262 | 28,281 | 0,344 | 4,53E-05 | 0,288 | 0,99 | 2,369 | 0,057 | 1 |
| *36,10* | *9,14* | ***-83,90%*** | *36,10* | *9,14* | ***-111,95%*** | *36,10* | *9,14* | ***-41,38%*** |
| *66,39* | *43,57* | ***-376,88%*** | *76,52* | *53,52* | ***-485,86%*** | *51,04* | *29,14* | ***-218,99%*** |
| ***Variable upper limit, variable costs*** | 0,242 | 23,915 | 0,01 | 0,00015 | 0,379 | 0,0047 | 2,310 | 0,129 | 0,0045 |
| *36,10* | *9,14* | ***-45,74%*** | *36,10* | *9,14* | ***-12,03%*** | *36,10* | *9,14* | ***14,10%*** |
| *52,61* | *30,38* | ***-232,47%*** | *40,45* | *18,79* | ***-105,69%*** | *31,01* | *12,68* | ***-38,75%*** |
| **USA** | | | | | | | | | |
|  | **Logistic Model** | | | **Bass Model** | | | **Gompertz Model** | | |
| ***Basic equation*** | 0,455 | 15,623 | 217,692 | 2,4E-05 | 0,267 | 402,256 | 3,059 | 0,190 | 318,884 |
| *340,92* | *148,27* | ***36,09%*** | *340,92* | *148,27* | ***3,60%*** | *340,92* | *148,27* | ***21,07%*** |
| *217,88* | *23,13* | ***84,40%*** | *328,65* | *118,43* | ***20,1%3*** | *269,09* | *66,85* | ***54,92%*** |
| ***Variable upper limit*** | 0,456 | 15,607 | 0,050 | 0 | 0,267 | 0,092 | 3,217 | 0,207 | 0,0667 |
| *340,92* | *148,27* | ***35,23%*** | *340,92* | *148,27* | ***3,48%*** | *340,92* | *148,27* | ***23,98%*** |
| *220,81* | *25,33* | ***82,92%*** | *329,04* | *120,67* | ***18,62%*** | *259,17* | *59,84* | ***59,65%*** |
| ***Variable upper limit, variable costs*** | 0,464 | 14,569 | 0,003 | 0 | 0,277 | 0,007 | 2,766 | 0,182 | 0,005 |
| *340,92* | *148,27* | ***26,00%*** | *340,92* | *148,27* | ***-2,58%*** | *340,92* | *148,27* | ***7,62%*** |
| *252,27* | *54,83* | ***63,02%*** | *349,71* | *141,88* | ***4,31%*** | *314,94* | *107,21* | ***27,70%*** |
| **ARGENTINA** | | | | | | | | | |
|  | **Logistic Model** | | | **Bass Model** | | | **Gompertz Model** | | |
| ***Basic equation*** | 2,023 | 16,907 | 0,586 | 2,95E-05 | 0,237 | 69,021 | 13,744 | 0,824 | 0,632 |
| *9,47* | *8,88* | ***93,80%*** | *9,47* | *8,88* | ***81,92%*** | *9,47* | *8,88* | ***93,33%*** |
| *0,59* | *0,00* | ***99,99%*** | *1,71* | *1,12* | ***87,39%*** | *0,63* | *0,04* | ***99,57%*** |
| ***Variable upper limit*** | 2,466 | 16,788 | 0,004 | 1,70172E-05 | 0,372 | 0,358 | 25,612 | 1,546 | 0,004 |
| *9,47* | *8,88* | ***93,89%*** | *9,47* | *8,88* | ***65,81%*** | *9,47* | *8,88* | ***93,71%*** |
| *0,58* | *0,00* | ***99,95%*** | *3,24* | *2,55* | ***71,29%*** | *0,60* | *0,01* | ***99,92%*** |
| ***Variable upper limit, variable costs*** | 3,401 | 16,688 | 0,0003 | 6,3E-06 | 0,622 | 0,011 | 6,077 | 0,357 | 0,00052 |
| *9,47* | *8,88* | ***92,57%*** | *9,47* | *8,88* | ***27,54%*** | *9,47* | *8,88* | ***87,91%*** |
| *0,70* | *0,12* | ***98,67%*** | *6,86* | *6,11* | ***31,15%*** | *1,15* | *0,43* | ***95,16%*** |
| **BRASIL** | | | | | | | | | |
|  | **Logistic Model** | | | **Bass Model** | | | **Gompertz Model** | | |
| ***Basic equation*** | 0,531 | 26,134 | 571,353 | 3,69E-06 | 0,776 | 57,237 | 4,797 | 0,202 | 179,988 |
| *57,01* | *35,39* | ***-254,49%*** | *57,01* | *35,39* | ***0,49%*** | *57,01* | *35,39* | ***-46,09%*** |
| *202,11* | *180,94* | ***-411,30%*** | *56,74* | *35,88* | ***-1,40%*** | *83,29* | *61,66* | ***-74,25%*** |
| ***Variable upper limit*** | 0,525 | 23,477 | 0,258 | 7,49E-06 | 0,780 | 0,094 | 3,619 | 0,120 | 1 |
| *57,01* | *35,39* | ***-96,10%*** | *57,01* | *35,39* | ***-1,02%*** | *57,01* | *35,39* | ***-76,22%*** |
| *111,80* | *90,67* | ***-156,23%*** | *57,60* | *36,80* | ***-4,00%*** | *100,47* | *79,64* | ***-125,05%*** |
| ***Variable upper limit, variable costs*** | 0,497 | 26,612 | 14079,39 | 6,54E-06 | 0,901 | 0,006 | 5,478 | 0,275 | 0,0077 |
| *57,01* | *35,39* | ***-240,11%*** | *57,01* | *35,39* | ***-1,88%*** | *57,01* | *35,39* | ***2,09%*** |
| *193,91* | *172,66* | ***-387,92%*** | *58,08* | *36,79* | ***-3,96%*** | *55,82* | *34,19* | ***3,37%*** |
| **UK** | | | | | | | | | |
|  | **Logistic Model** | | | **Bass Model** | | | **Gompertz Model** | | |
| ***Basic equation*** | 0,338 | 20,589 | 88,387 | 0 | 0,273 | 140,633 | 2,473 | 0,088 | 292,222 |
| *75,61* | *35,34* | ***4,00%*** | *75,61* | *35,34* | ***-10,12%*** | *75,61* | *35,34* | ***-4,60%*** |
| *72,58* | *32,39* | ***8,33%*** | *83,26* | *44,54* | ***-26,05%*** | *79,09* | *40,62* | ***-14,95%*** |
| ***Variable upper limit*** | 0,331 | 22,315 | 0,368 | 0 | 0,268 | 0,636 | 2,651 | 0,093 | 1 |
| *75,61* | *35,34* | ***-12,77%*** | *75,61* | *35,34* | ***-25,80%*** | *75,61* | *35,34* | ***-10,91%*** |
| *85,27* | *45,33* | ***-28,27%*** | *95,12* | *55,78* | ***-57,87%*** | *83,86* | *44,93* | ***-27,14%*** |
| ***Variable upper limit, variable costs*** | 0,303 | 22,368 | 0,039 | 0 | 0,271 | 0,066 | 2,543 | 0,105 | 0,070 |
| *75,61* | *35,34* | ***-18,69%*** | *75,61* | *35,34* | ***-18,07%*** | *75,61* | *35,34* | ***5,65%*** |
| *89,75* | *49,78* | ***-40,88%*** | *89,28* | *50,36* | ***-42,51%*** | *71,34* | *34,88* | ***1,27%*** |
| **GERMANY** | | | | | | | | | |
|  | **Logistic Model** | | | **Bass Model** | | | **Gompertz Model** | | |
| ***Basic equation*** | 0,198 | 16,079 | 97,923 | 0,005 | 0,084 | 282,695 | 1,594 | 0,150 | 75,336 |
| *130,97* | *50,34* | ***35,00%*** | *130,97* | *50,34* | ***26,77%*** | *130,97* | *50,34* | ***47,53%*** |
| *85,13* | *16,56* | ***67,10%*** | *95,90* | *29,18* | ***42,04%*** | *68,72* | *8,08* | ***83,94%*** |
| ***Variable upper limit*** | 0,183 | 16,848 | 0,167 | 0,002 | 0,07 | 0,99 | 1,419 | 0,077 | 0,258 |
| *130,97* | *50,34* | ***35,29%*** | *130,97* | *50,34* | ***20,95%*** | *130,97* | *50,34* | ***33,06%*** |
| *84,75* | *15,99* | ***68,23%*** | *103,53* | *33,29* | ***33,87%*** | *87,67* | *19,30* | ***61,67%*** |
| ***Variable upper limit, variable costs*** | 0,098 | 35,573 | 0,117 | 0,0033 | 0,0678 | 1,152 | 1,057 | 0,052 | 0,029 |
| *130,97* | *50,34* | ***18,07*** | *130,97* | *50,34* | ***21,35%*** | *130,97* | *50,34* | ***28,56%*** |
| *107,29* | *36,07* | ***28,35*** | *103,00* | *32,86* | ***34,72%*** | *93,56* | *25,58* | ***49,19%*** |
| **FRANCE** | | | | | | | | | |
|  | **Logistic Model** | | | **Bass Model** | | | **Gompertz Model** | | |
| ***Basic equation*** | 0,443 | 15,676 | 22,841 | 0,0008 | 0,233 | 102,20 | 2,642 | 0,148 | 44,130 |
| *40,60* | *19,25* | ***44,62%*** | *40,60* | *19,25* | ***-13,54%*** | *40,60* | *19,25* | ***23,12%*** |
| *22,49* | *2,56* | ***86,68%*** | *46,10* | *24,75* | ***-28,55%*** | *31,22* | *9,87* | ***48,75%*** |
| ***Variable upper limit*** | 0,452 | 15,551 | 0,039 | 0,00088 | 0,476 | 0,038 | 3,228 | 0,209 | 0,052 |
| *40,60* | *19,25* | ***45,91%*** | *40,60* | *19,25* | ***47,25%*** | *40,60* | *19,25* | ***36,74%*** |
| *21,96* | *2,25* | ***88,33%*** | *21,42* | *1,53* | ***92,05%*** | *25,69* | *5,55* | ***71,16%*** |
| ***Variable upper limit, variable costs*** | 0,475 | 14,391 | 0,0027 | 0,00119 | 0,549 | 0,0028 | 2,084 | 0,099 | 0,009 |
| *40,60* | *19,25* | ***38,71%*** | *40,60* | *19,25* | ***39,56%*** | *40,60* | *19,25* | ***3,33%*** |
| *24,89* | *5,06* | ***73,72%*** | *24,54* | *4,60* | ***76,10%*** | *39,25* | *17,33* | ***9,97%*** |
| **SWEDEN** | | | | | | | | | |
|  | **Logistic Model** | | | **Bass Model** | | | **Gompertz Model** | | |
| ***Basic equation*** | 0,318 | 24,471 | 81,481 | 0 | 0,299 | 34,174 | 2,888 | 0,127 | 60,052 |
| *28,07* | *11,80* | ***-57,69%*** | *28,07* | *11,80* | ***8,63%*** | *28,07* | *11,80* | ***-1,75%*** |
| *44,27* | *28,34* | ***-140,14%*** | *25,65* | *12,16* | ***-2,99%*** | *28,56* | *13,81* | ***-16,97%*** |
| ***Variable upper limit*** | 0,306 | 25,446 | 0,643 | 0 | 0,290 | 0,568 | 2,674 | 0,091 | 1 |
| *28,07* | *11,80* | ***-80,17%*** | *28,07* | *11,80* | ***-42,53%*** | *28,07* | *11,80* | ***-39,13%*** |
| *50,58* | *34,83* | ***-195,10%*** | *40,01* | *25,02* | ***-111,94%*** | *39,06* | *23,79* | ***-101,57%*** |
| ***Variable upper limit, variable costs*** | 0,297 | 27,286 | 58768,013 | 0 | 0,296 | 0,044 | 2,956 | 0,156 | 0,0179 |
| *28,07* | *11,80* | ***-102,02%*** | *28,07* | *11,80* | ***-29,50%*** | *28,07* | *11,80* | ***5,40%*** |
| *56,71* | *40,85* | ***-246,09%*** | *36,35* | *21,60* | ***-83,00%*** | *26,56* | *13,17* | ***-11,54%*** |
| **CHINA** | | | | | | | | | |
|  | **Logistic Model** | | | **Bass Model** | | | **Gompertz Model** | | |
| ***Basic equation*** | 0,625 | 17,033 | 211,646 | 6,16E-05 | 0,709 | 197,444 | 2,855 | 0,107 | 1499,92 |
| *466,50* | *280,91* | ***54,94%*** | *466,50* | *280,91* | ***57,68%*** | *466,50* | *280,91* | ***0,47%*** |
| *210,20* | *27,19* | ***90,32%*** | *197,41* | *11,82* | ***95,79%*** | *464,31* | *263,45* | ***6,22%*** |
| ***Variable upper limit*** | 0,628 | 15,923 | 0,034 | 0,00014 | 0,848 | 0,032 | 5,422 | 0,355 | 0,038 |
| *466,50* | *280,91* | ***45,07%*** | *466,50* | *280,91* | ***47,99%*** | *466,50* | *280,91* | ***39,64%*** |
| *256,23* | *71,91* | ***74,40%*** | *242,64* | *59,71* | ***78,74%*** | *281,58* | *95,26* | ***66,09%*** |
| ***Variable upper limit, variable costs*** | 0,678 | 15,251 | 0,0024 | 0,00016 | 0,955 | 0,0024 | 1,963 | 0,083 | 0,010 |
| *466,50* | *280,91* | ***36,52%*** | *466,50* | *280,91* | ***38,54%*** | *466,50* | *280,91* | ***-1,07%*** |
| *296,13* | *110,55* | ***60,64%*** | *286,69* | *102,54* | ***63,50%*** | *471,49* | *273,41* | ***2,67%*** |
| **AUSTRALIA** | | | | | | | | | |
|  | **Logistic Model** | | | **Bass Model** | | | **Gompertz Model** | | |
| ***Basic equation*** | 0,318 | 17,352 | 16,434 | 0,0016 | 0,353 | 15,838 | 2,199 | 0,101 | 39,017 |
| *22,61* | *10,77* | ***33,17%*** | *22,61* | *10,77* | ***32,82%*** | *22,61* | *10,77* | ***15,98%*** |
| *15,11* | *3,62* | ***66,39%*** | *15,19* | *3,35* | ***68,86%*** | *18,99* | *7,17* | ***33,47%*** |
| ***Variable upper limit*** | 0,290 | 18,144 | 0,0735 | 0,00267 | 0,328 | 0,063 | 2,1085 | 0,087 | 0,198 |
| *22,61* | *10,77* | ***23,94%*** | *22,61* | *10,77* | ***31,25%*** | *22,61* | *10,77* | ***8,27%*** |
| *17,20* | *5,70* | ***47,10%*** | *15,54* | *4,03* | ***62,60%*** | *20,74* | *9,14* | ***15,19%*** |
| ***Variable upper limit, variable costs*** | 0,262 | 16,786 | 0,005 | 0,005 | 0,352 | 0,0047 | 1,916 | 0,0918 | 0,0117 |
| *22,61* | *10,77* | ***17,21%*** | *22,61* | *10,77* | ***24,47%*** | *22,61* | *10,77* | ***2,86%*** |
| *18,72* | *7,18* | ***33,34%*** | *17,07* | *5,54* | ***48,58%*** | *21,96* | *10,15* | ***5,76%*** |

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