The Decline in the Use of Native Language Among Native Kabardians

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Abstract
This project explores the decline in the use of the Kabardian language among native speakers in the Kabardino-Balkarian Republic, Russian Federation. The model was built to simulate the complex dynamics of language extinction: how education, perceived utility, and economic pressures interact to reduce intergenerational transmission of the native language. Based on historical census data, stakeholder interviews, and academic sources, the study finds that without any interventions the Kabardian language will likely become extinct by the end of this century.
Two policies were tested: one boosting engaging Kabardian-language media, and another mandating minimum school hours. The results showed potential in reversing the trend when applied consistently over time. The model still has its limitations, but even in the current form, it offers insight into the systemic nature of language loss. More importantly, it reminds us that language is not just a communication tool, it's a vessel for identity, community, history, and culture.

1. Introduction and Reference Mode

"There are more than 7,000 languages on Earth, yet half of the world's 7.6 billion people speak just 24 of them and 95 percent speak just 400 of them. That leaves five percent of the global population spread across 6,600 different languages, hundreds of them now spoken by less than ten people."(University of Florida International Center, n.d.).
Kabardian (Circassian) is a language native to Northwest Caucasus, Russia, and is one of those that are recognized as endangered (Applebaum, 2010). The factors such as globalization, urbanization, and the dominance of Russian as the state language are continuously lowering the perceived utility of Kabardian language resulting in weakened intergeneration transmission of the language. Proficiency in Russian language is necessary for obtaining education and better career prospects, therefore the less institutional support for Kabardian is observed, further driving the decline. Such patterns are not unique to Kabardian but reflect a global phenomenon in which dominant languages marginalize minority ones, diminishing linguistic diversity (Atifnigar, 2021).
As highlighted by the Endangered Languages Project, "language extinction represents not just the loss of words but the disappearance of entire cultural frameworks and worldviews". This loss is not merely linguistic but cultural, severing ties to traditional knowledge systems and community identity.

The Reference Mode:
The graphs below demonstrate the population census data on the Kabardian population ("Native Population") and Kabardian language speakers ("Native Speakers") from the official documentation of the USSR (1939-1989) and Russian Federation (2002-2020). During this period, both the Native Population and Native Speakers showed consistent growth until 2010, with the value being very close to each other. This means that the majority of native people were able to freely communicate in their native

language. However, this trend changed significantly after 2010: while the Native Population continued increasing, the number of Native Speakers showed a sharp decline. This highlights a critical drop in the transmission and use of the Kabardian language.
The graphs also illustrate two possible scenarios for the future trajectory of the Kabardian language between 2020 and 2040. The Native Population values for 2020 to 2040 are predicted assuming the growth rate remains consistent at 2.71% annually. In the "Feared Scenario" (Figure 1) the number of native speakers continues to decline with the same rate as was observed from 2010 to 2020 despite steady population growth, reflecting an alarming trend of language loss. The Native Language Speakers values for the Feared Scenario from 2020 to 2040 are predicted based on assuming the continuation of the historical trends observed post-2002. On the contrary, the "Wishful Scenario" (Figure 2) shows a more optimistic future, where the number of native speakers grows in parallel with the population as it was from 1939 to 2010. However, this outcome is purely aspirational and lacks support from historical trends.

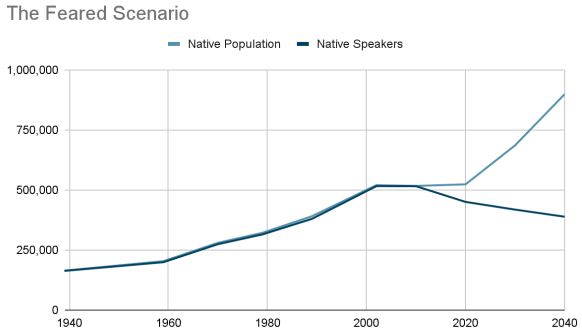


Figure 1. The Feared Scenario

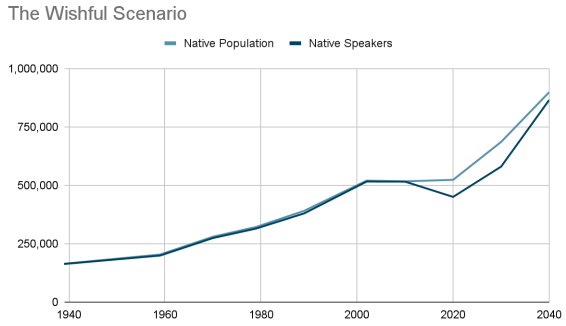


Figure 2. The Wishful Scenario

2. Hypothesis

The hypothesis for the Kabardian language extinction model was inspired by the Bass Diffusion Model, the insights shared by philologist and university lecturer at Kabardino-Balkarian State University during a personal interview, as well as the literature review. Together these resources helped to trace the cause and effect of economic, educational, and social dynamics on the language extinction.
As economic opportunities increasingly favor Russian, Kabardian is perceived as not essential for education and employment, which subsequently leads to a decrease in institutional and social support for Kabardian. A clear example is the reduction in hours dedicated to Kabardian as a subject in schools, dropping from five hours per week in the 1980s to just two hours per week today (Anonymous Expert, personal interview, 24 November 2024). This structural decline repeats the global patterns of linguistic shift documented in studies of other endangered languages (Atifnigar, 2021).
The system dynamics model developed includes several feedback loops that illustrate these processes, highlighting the connection between economic pressures, language utility, education, and speaker dynamics.

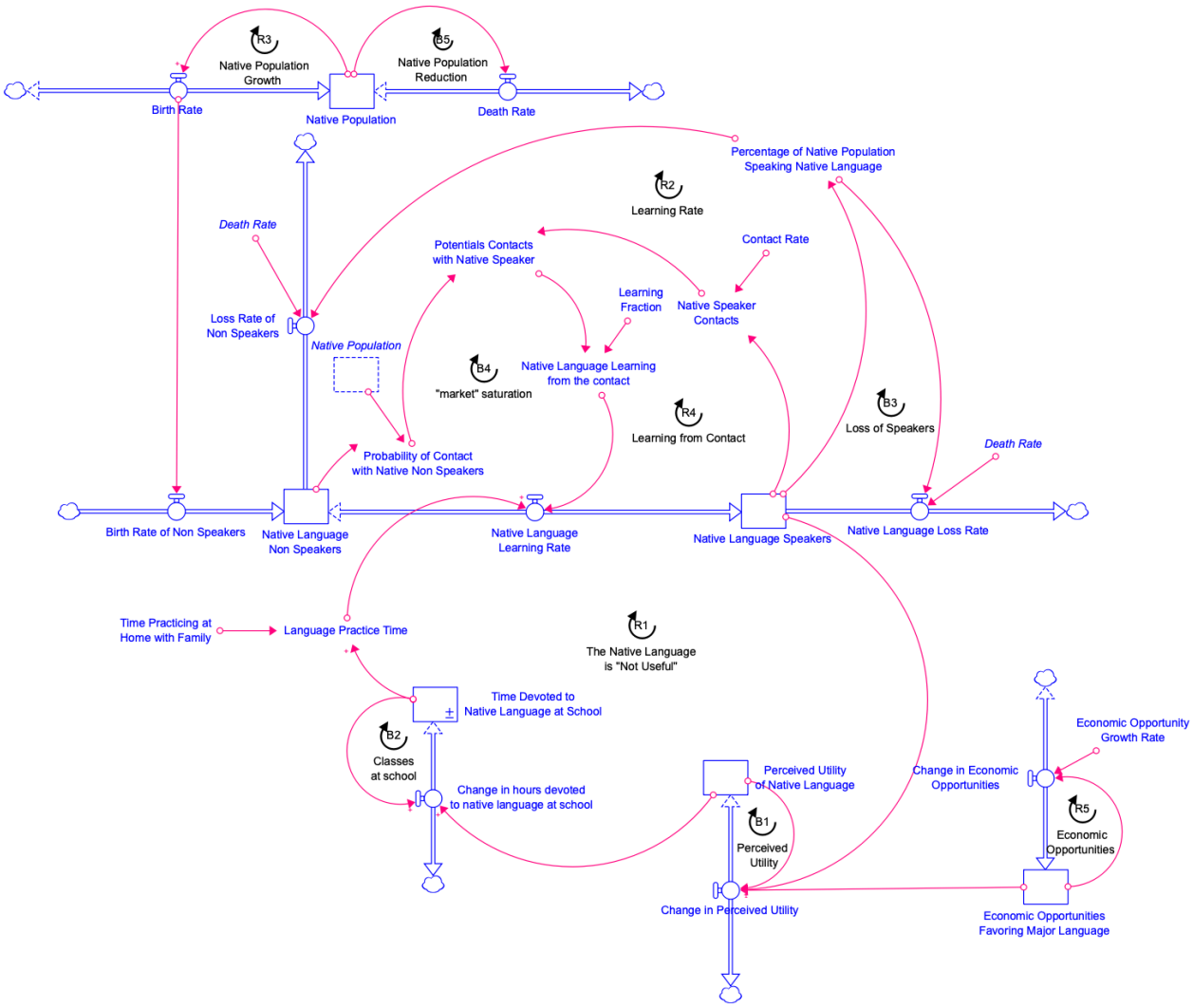


Figure 3. The Hybrid Stock-Flow Diagram

Key Loops

R2: *Learning Rate.*
Inspired by the Bass Diffusion Model, this loop demonstrates the potential for Kabardian adoption among non-speakers through social interactions and exposure. Higher contact rates between speakers and non-speakers drive language learning. The importance of sustained and meaningful exposure to language input has been discussed by multiple second language acquisition (SLA) frameworks, particularly those emphasizing informal learning settings (Bahrani, Sim, & Nekoueizadeh, 2014). However, this loop's impact is limited as the number of native speakers declines as well as the educational opportunities.
B2: *Classes at School.*
This balancing loop demonstrates the important role of the education system in preserving Kabardian.

As institutional priorities shift favoring the dominant language, the perceived utility of Kabardian decreases. The hours for teaching Kabardian language at school have been drastically reduced, weakening the loop's ability to act against language attrition.
B3: *Loss of Speakers Loop.*
This balancing loop shows the dynamics of language attrition. As perceived utility of Russian language increases, the perceived utility of Kabarian language declines. This creates a self-reinforcing decline in the number of native speakers, reducing opportunities for language adoption and further driving language loss.
R3: *Population Growth Loop.*
This reinforcing loop shows how the growth of the Kabardian population creates more room for language transmission. However, as the Perceived Utility of Native Language stock declines, the potential for intergenerational transmission decreases, resulting in a weakened positive effect of population growth.
R5 *Economic Opportunities and B1 Perceived Utility.*
These loops show how economic opportunities favoring Russian reduce the perceived utility of Kabardian. As natives prioritize learning Russian seeking better career prospects, institutional support for Kabardian declines, creating a feedback cycle that keeps driving the language loss.

3. Assumptions

The model assumes that the decline of the Kabardian language is primarily driven by a combination of social, economic, and educational factors within the Kabardian population in Russia, leaving out other factors that might contribute to the problem.
The findings produced by this model are strictly limited to the context of Kabardians in Russia. The structure of the model reflects the core dynamics of language decline but remains incomplete due to time constraints. Globalization, urban migration, media representation, and nuances of generational transmission are factors that were discussed in both the article by Atifnigar (2021) and during the interview with an expert, a philologist at Kabardino-Balkarian State University. Some of these elements have been included into the current model (e.g., economic utility and education system feedback loops), but others have been omitted. Future iterations of the model aim to take into account these additional factors to provide a more comprehensive understanding of the problem.

Key assumptions of the model include:
Geographic Scope: The model focuses exclusively on Kabardian speakers in Russia and does not account for Kabardians living in diaspora communities in other countries such as Turkey and Jourdan.
Time Frame: The model assumes that the current trends observed over the last two decades will continue unless significant interventions are implemented (worse case scenario).
Simplified Economic Dynamics: Economic opportunities favoring the Russian language are represented on a scale from 1 to 10 and use an assumed stable annual growth of 0.02 which directly influences the perceived utility of Kabardian. The broader economic trends were not explored for this research.
Education System: The model assumes that the decline in teaching hours for Kabardian in schools is linear, from 5 hours per week to 2 hours per week in 2024; the model is designed to make it possible to have no school hours dedicated to Kabardian. Future improved models could account for non-linear dynamics such as policy shifts or community advocacy.
Population Dynamics: The native population grows at an assumed constant annual rate of 2.71%, as observed in historical census data from previous years. This growth indirectly impacts language transmission rates.

4. Model Validation

Parameter Confirmation Test

The parameters that model uses were taken from historical census data, an interview with an expert, and academic research. The historical decline in instructional hours for Kabardian was verified through both the interview and official educational policy records. The model does include several variables that are primarily assumed or estimated due to the lack of direct academic evidence. These variables are based on stakeholder input, reasonable estimates, or simplified representations of complex systems. Some of them such as Time to Adjust the Perceived Utility, Effect of Economic Opportunities Graphical Function, Adoption Multiplier Graphical Function, Effect of Relative Native Speakers and Perceived Utility of the Language on School Hours, are assumed, the remaining parameters are supported to varying degrees by empirical data or scholarly work.

Such variables are:

- Base Practice Time (35 Hours/Week): Although there is no academic consensus regarding how many hours a person should be practicing a language in order to be completely fluent, there is solid theoretical backing for why extended exposure to language input is essential to language acquisition, especially in informal settings (Bahrani, Sim, and Nekoueizadeh 2014).
- Learning Fraction (2%): Krashen (1982) argued that effective language acquisition requires learners to be actively engaged with comprehensible input whether in formal education or informal settings. This significantly lowers the Learning fraction as only very few interactions outside of the classroom lead to learning the language.
- Contact Rate (65 Contacts/Year): This estimation reflects the relatively low population density and the predominance of small towns in the Kabardino-Balkarian Republic, where the Kabardian language is spoken. Unlike larger urban centers, these smaller communities offer fewer opportunities for unique individual contacts throughout the year.
- Economic Opportunity Growth Rate (0.02): This value represents a rough estimate of the annual GDP growth rate in the Kabardino-Balkarian Republic, where Kabardian is one of the state languages. N
- Time to Adjust Hours (6 Years): This estimate is based on observations showing that, from 2002 to 2024, the number of hours dedicated to Kabardian language instruction steadily declined - from 5 hours per week to just 2 hours per week.

Extreme Condition Test

Extreme condition tests were conducted by setting parameters the "Learning Fraction" and "Contact Rate" to their maximum and minimum values. The model showed consistent behavior, no unrealistic or out of character outcomes, confirming the robustness of its structural integrity under extreme scenarios (see result in Appendix, figure 9-14).

Dimensional Consistency Test

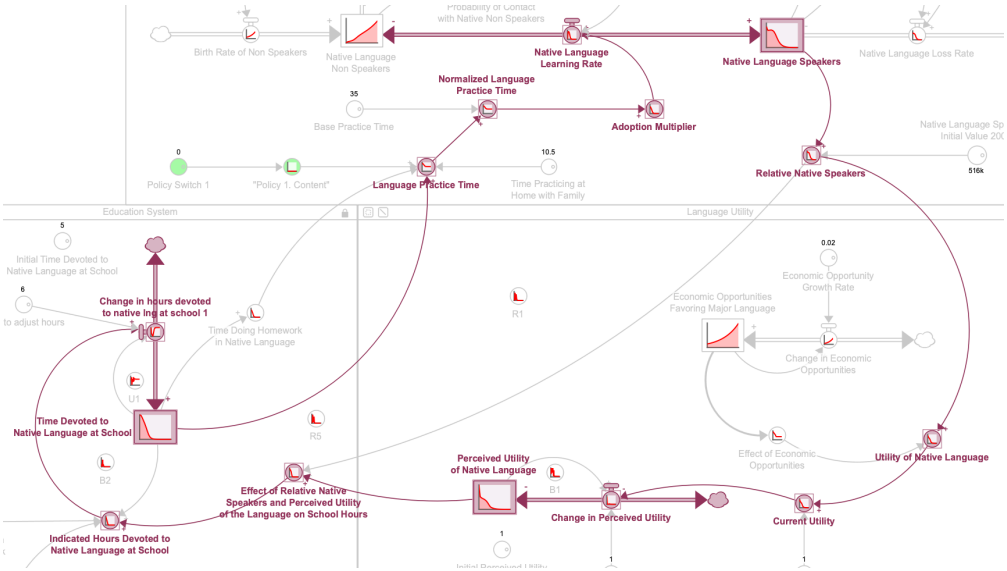
The equations and units in the model were verified using Stella Architect's built-in validation tools to ensure mathematical accuracy and consistency across all parameters.

5. Model Analysis

The base run of the Language Extinction Model was conducted to simulate the dynamics of Kabardian language loss under the current socio-economic and educational conditions. The purpose of the model is to try to understand the interaction of reinforcing and balancing feedback loops driving the decline of native language speakers.

Initial Observations

The model illustrates a severe decline in native language speakers and nearly complete extinction by 2100. The Base run of the model aligns with the scientist prediction of losing many endangered languages: “between 50% and 90% of the world’s 7,000 languages will be extinct by 2150” (*The Guardian view on endangered languages*, 2024).

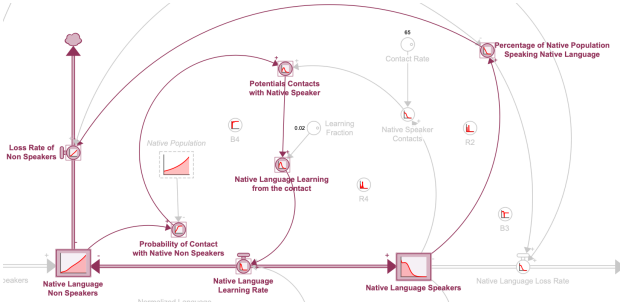


This behavior is produced due to the dominating reinforcing loop the "The Native Language is “Not Useful”" feedback (R1) (Figure 4) which reduces the perceived utility of Kabardian, lowering the "Time Devoted to Native Language at School" and overall transmission rates.

Figure 4. "The Native Language is “Not Useful”" feedback loop

Language balancing feedback loop (B1) aims to stabilize or slow the decline in perceived utility by counteracting significant changes. However, the strength of the opposite forces, such as economic opportunities favoring Russian, outweighs this stabilizing effect, leading to a steady decline in utility over time.

The feedback interaction shows how a decrease in perceived utility creates a reinforcing effect on its own decline. As perceived utility falls, the language becomes less relevant in education as well as daily life. The balancing loop "Time Devoted to Native Language at School" attempts to stabilize native language learning at school by maintaining a baseline transmission rate through minimal educational efforts (2 hours per week). This impact is not strong enough compared to the dominant reinforcing loops. The "Time Devoted to Native Language at School" component demonstrates a decline due to reduced perceived utility (a function of economic pressures and language adoption rates). As per the interview with an expert historically, five hours per week were allocated to teaching Kabardian. This has decreased to two hours due to structural changes in educational policies and reduced utility which the model accurately represents.



Reinforcing loop R4 Learning Rate (Figure 5) increases learning and use of the language when conditions are good. When the population of native speakers is high, there are more opportunities for contact and language learning. This leads to continuous increase in the stock of speakers, strengthening the loop.

Figure 5. "Learning Rate" feedback loop

However, if the percentage of native speakers drops below a critical threshold, the probability of contact and therefore learning Kabardian decreases significantly. This creates a reinforcing decline, accelerating language extinction. The loop demonstrates the importance of maintaining a critical mass of native speakers to sustain language learning.
B3 loop demonstrates the process of losing speakers, where a decreasing number of native speakers increases the native language loss rate. This creates a reinforcing decline in the overall speaker population.
The loop dominance analysis reveals that the balancing loop "Perceived Utility" B1 is the most influential over the long term, contributing to 91.07% of the model's behavior by 2100. This means that the decline in native language speakers is mostly driven by the reinforcing effects of declining perceived utility and transmission of the language. This dominance shows the need for interventions which would target the root causes of language loss, such as enhancing perceived utility and opportunities for language learning.

6. Policy

The Base Run shows how critical the problem of language extinction is. Here are the results showing that if the number of hours will keep being decreased, the perceived utility of the language will drop close to 0 subsequently result in almost complete extinction of the Kabardian language:

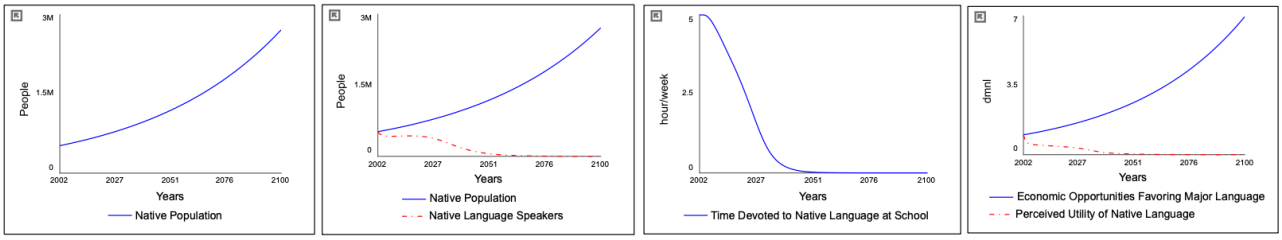


Figure 6. Model Base Run

The intervention is necessary in order to preserve the Kabardian language as well as the 3 thousand years old culture that this language carries. Here are the policies I suggest implementing to ensure the generational transmission of Kabardian language:

Policy 1: Investing in Entertaining and Modern Content in Kabardian
This policy focuses on increasing the amount of time native speakers spend practicing the Kabardian language by introducing engaging and modern content in the language. By dedicating an additional two hours per week to consuming Kabardian media, this policy strengthens the reinforcing feedback loops associated with language practice and adoption. The results indicate that implementing this policy leads to an increase in the number of Kabardian speakers. As more people speak the language, its perceived usefulness among native speakers rises, which in turn prompts an increase in school hours dedicated to Kabardian. This positive feedback loop continually reinforces both the learning and use of the language among the native population.

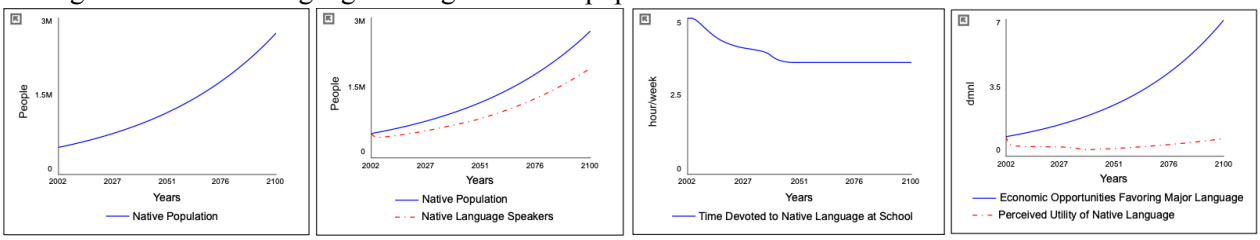


Figure 7. The result of the Implementation of "Policy 1. Content."

Policy 2: Government Intervention to Maintain Minimum School Hours

This policy enforces a government regulation to allocate at least four hours per week to teaching Kabardian at schools. By stabilizing the "Time Devoted to Native Language at School" stock, the policy reinforces the balancing loop aimed at maintaining transmission rates.

The results show that this policy helps slow the decline of native speakers by fixing a major weakness in the education system. However, the policy's effect only lasts as long as the government keeps the rule in place. If the required school hours for the Kabardian language are reduced again, the number of native speakers quickly drops. This means the positive changes will not last unless the support is ongoing.

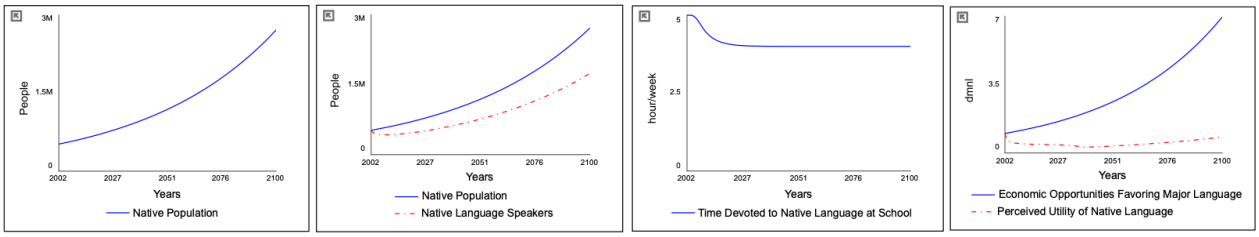


Figure 8. The result of the Implementation of "Policy 2. School Hours."

In the further research I will explore case studies from other countries facing similar challenges to see what policy interventions have been implemented and which have proven successful. In particular, I plan to focus on identifying more nuanced, cost-effective, and potentially overlooked leverage points such as community-based initiatives, media engagement, and informal education programs.

7. Conclusion

The Language Extinction model provides valuable insights into the main drivers behind the decline of the Kabardian language, including economic pressures, decreasing perceived utility of the language, and reduced institutional support within the education system. The proposed policies offer different degrees of success in addressing the problem. Policy 1 demonstrates that increasing exposure to Kabardian content boosts the time spent practicing the language, strengthening feedback loops that support its use. Policy 2 highlights the importance of maintaining educational structures to ensure a steady baseline of language transmission in schools.

However, the model has limitations and cannot yet be considered fully reliable. It lacks structures to account for additional critical factors contributing to the decline and preservation of the Kabardian language. Furthermore, it simplifies economic dynamics and assumes linear trends in educational changes, which may not fully represent the complexities of real-world systems.

Future versions of the model should incorporate these missing elements to provide a more accurate and comprehensive picture of the factors influencing language extinction. Despite its current limitations, the model offers an important foundation for understanding the systemic pressures on endangered languages like Kabardian and evaluating potential policies to preserve linguistic and cultural heritage.

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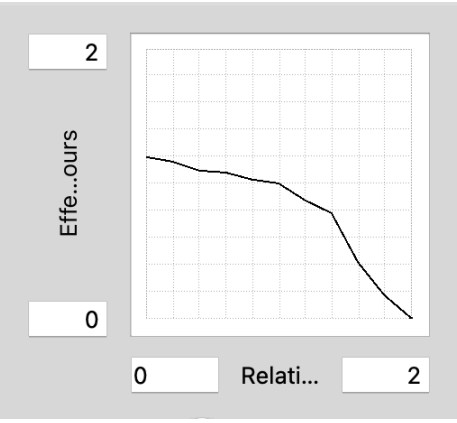
Appendix

Documentation

{ The model has 46 (46) variables (array expansion in parens).
In root model and 0 additional modules with 4 sectors.
Stocks: 6 (6) Flows: 9 (9) Converters: 31 (31)
Constants: 16 (16) Equations: 24 (24) Graphicals: 3 (3) }

****
Education_System:
****
Change_in_hours_devoted_to_native_lng_at_school_1 =
(Indicated_Hours_Devoted_to_Native_Language_at_School
-Time_Devoted_to_Native_Language_at_School)/Time_to_adjust_hours
UNITS: hour/week/Years
DOCUMENT: The rate of change in hours devoted to the native language at school. It is calculated as the difference between the indicated hours and the current stock level, adjusted over a specific time period.

Effect_of_Relative_Native_Speakers_and_Perceived_Utility_of_the_Language_on_School_Hours =
GRAPH(Relative_Native_Speakers*Perceived_Utility_of_Native_Language)
Points: (0.000, 1.196), (0.200, 1.162), (0.400, 1.095), (0.600, 1.028), (0.800, 0.961), (1.000, 0.849), (1.200, 0.749), (1.400, 0.581), (1.600, 0.413), (1.800, 0.168), (2.000, 0.000)



UNITS: dmnl
DOCUMENT: When the relative number of native speakers is high, schools maintain a recommended amount of hours for the language. However, as this ratio declines, institutional support weakens, leading to complete removal from the curriculum.
The choice of points reflects a nonlinear decline:
High Values **(0.000, 1.196)**: Even when relative speakers and utility are at their lowest, some institutional support exists.
Mid-range Values **(1.000, 1.000)**: With the influence declining, fewer hours are devoted to teaching the language, showing decreasing institutional interest.
Low Values **(2.000, 0.000)**: When the relative speakers and perceived utility are at lowest, schools cease teaching the language entirely.

Indicated_Hours_Devoted_to_Native_Language_at_School =
MAX(MIN(Upper_Limit_on_hours_per_week,
Effect_of_Relative_Native_Speakers_and_Perceived_Utility_of_the_Language_on_School_Hours*Time_Devoted_to_Native_Language_at_School), Lower_Limit_on_hours_per_week)
UNITS: hour/week
DOCUMENT: The suggested weekly amount of hours for the native language, considering the school constraints (upper and lower limits) and societal factors like relative speakers and perceived utility.

Initial_Time_Devoted_to_Native_Language_at_School = 5
UNITS: hour/week

DOCUMENT: The initial stock value for the time devoted to teaching the native language. Based on stakeholders input.

Lower_Limit_on_hours_per_week = 2
UNITS: hour/week
DOCUMENT: The minimum number of hours that can be allocated for teaching the native language at school. Assumed that the hours allocated will not go below the 2024 norm.

Time_Devoted_to_Native_Language_at_School(t) = Time_Devoted_to_Native_Language_at_School(t - dt) + (- Change_in_hours_devoted_to_native_lng_at_school_1) * dt {NON-NEGATIVE}
INIT Time_Devoted_to_Native_Language_at_School = Initial_Time_Devoted_to_Native_Language_at_School
UNITS: hour/week
DOCUMENT: The number of hours per week dedicated to teaching the native language in schools. It reflects the institutional support for the language. Due to the limitations of the model this stock had to be represented as non-negative as hours/weeks cannot drop below 0.

Time_Doing_Homework_in_Native_Language = Time_Devoted_to_Native_Language_at_School/2
UNITS: hour/week
DOCUMENT: The additional time students spend doing homework in the native language, which may indirectly influence the system. As per stakeholders, they spend half the time spent in the classroom on homework.

Time_to_adjust_hours = 6
UNITS: Years
DOCUMENT: The time required to adjust the hours devoted to teaching the native language in response to changes in indicated hours. As per stakeholder, 6 years is the average amount of years when the changes in school hours are adjusted.

Upper_Limit_on_hours_per_week = 6
UNITS: hour/week
DOCUMENT: The maximum number of hours that can be allocated for teaching the native language at school. This number cannot be higher so the students still have an appropriate amount of hours allocated to other subjects at school.

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Language_Adoption:
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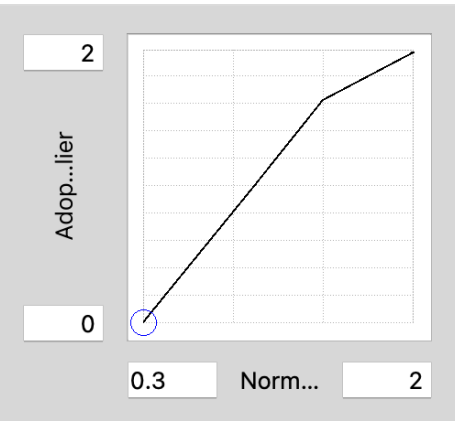


Adoption_Multiplier = GRAPH(Normalized_Language_Practice_Time)
Points: (0.300, 0.000), (0.866666666667, 0.816), (1.43333333333, 1.631), (2.000, 1.978)
UNITS: dmnl
DOCUMENT: Represents how the normalized language practice time influences the learning of the native language.
High Values (0.300, 0.000): Minimal adoption due to lack of exposure.
Mid-range Values (1.000, 1.000): A steep rise in adoption efficiency as practice time increases.

Low Values (2.000, 2.000): Adoption rates begin to stabilize, showing diminishing returns with excessive practice time.

Base_Practice_Time = 35
  UNITS: hour/week
  DOCUMENT: The baseline amount of time individuals should spend speaking, listening, consuming content in the language under normal circumstances to be able to classify it as their primary language. This number is assumed.

Bahrani, T., Sim, T. S., & Nekoueizadeh, S. (2014). *Second language acquisition in informal setting*. Theory and Practice in Language Studies, 4(8), 1714–1723. https://doi.org/10.4304/tpls.4.8.1714-1723

Birth_Rate_of_Non_Speakers = Birth_Rate {UNIFLOW}
  UNITS: people/Years
  DOCUMENT: The number of people added to the native population annually based on the fractional birth rate. The same as the Birth Rate as everyone is born a non language speaker.

Contact_Rate = 65
  UNITS: dmnl/year
  DOCUMENT: Rate of interactions. This number assumes that there are on average 65 meaningful contacts per year.

Language_Practice_Time =
Time_Practicing_at_Home_with_Family+Time_Devoted_to_Native_Language_at_School+Time_Doing_Homework_in_Native_Language
  UNITS: hour/week
  DOCUMENT: Total time individuals spend practicing the language, which includes both base practice and additional practice with family.

Learning_Fraction = 0.02
  UNITS: dmnl
  DOCUMENT: Fraction of contacts that result in successful learning of the native language. This number assumes that 2% of the meaningful interactions between Native language speakers and non-speaker could positively result in learning the language. This number is small as everyone can speak Russian and for convenience prefer to use it other than any of the Native languages.

Krashen, S. (1982). *Principles and practice in second language acquisition*. New York: Prentice Hall.

Loss_Rate_of_Non_Speakers =
Death_Rate*(1-Percentage_of_Native_Population_Speaking_Native_Language) {UNIFLOW}
  OUTFLOW PRIORITY: 1
  UNITS: People/year
  DOCUMENT: The outflow of non-speakers from the population, influenced by natural mortality.

Native_Language_Learning_from_the_contact =
Learning_Fraction*Potentials_Contacts_with_Native_Speaker
  UNITS: People/year
  DOCUMENT: The number of people learning the native language through interpersonal contact.

Native_Language_Learning_Rate =
Native_Language_Learning_from_the_contact*Adoption_Multiplier
  OUTFLOW PRIORITY: 2
  UNITS: People/year
  DOCUMENT: Rate at which people learn the native language based on contact and practice.

Native_Language_Loss_Rate =
Death_Rate*Percentage_of_Native_Population_Speaking_Native_Language {UNIFLOW}
  UNITS: People/year
  DOCUMENT: The rate of a native language speakers dying. Due to limitations this model omits the fact that someone who once was able to speak native language might forget it during their lifetime.

Native_Language_Non_Speakers(t) = Native_Language_Non_Speakers(t - dt) +
(Birth_Rate_of_Non_Speakers - Loss_Rate_of_Non_Speakers - Native_Language_Learning_Rate) * dt
{NON-NEGATIVE}
  INIT Native_Language_Non_Speakers = Native_Population-Native_Language_Speakers
  UNITS: People
  DOCUMENT: People in the native population who do not speak the native language.

Native_Language_Speakers(t) = Native_Language_Speakers(t - dt) + (Native_Language_Learning_Rate - Native_Language_Loss_Rate) * dt {NON-NEGATIVE}
  INIT Native_Language_Speakers = Native_Language_Speakers_Initial_Value_2002
  UNITS: People
  DOCUMENT: People who speak the native language.

Native_Language_Speakers_Initial_Value_2002 = 516053
  UNITS: People
  DOCUMENT: The number of people who identified as Kabardian language speakers in 2002 during the Russian Federation Population Census.

Federal State Statistics Service. (2002). Itogi Vserossiyskoy perepisi naseleniya 2002 goda [Results of the All-Russian Population Census 2002]. Retrieved from http://www.perepis2002.ru/index.html?id=17

Native_Speaker_Contacts = Contact_Rate*Native_Language_Speakers
  UNITS: People/year
  DOCUMENT: Rate at which native language speakers engage in contacts with non-speakers.

Normalized_Language_Practice_Time = Language_Practice_Time/Base_Practice_Time
  UNITS: dmnl
  DOCUMENT: This variable adjusts the current practice time against a baseline, ensuring the consistent scaling across functions.

Percentage_of_Native_Population_Speaking_Native_Language =
Native_Language_Speakers/Native_Population
  UNITS: dmnl
  DOCUMENT: The proportion of the native population actively speaking the language.

Potentials_Contacts_with_Native_Speaker =
Probability_of_Contact_with_Native_Non_Speakers*Native_Speaker_Contacts

UNITS: People/year
DOCUMENT: Number of interactions between non-speakers and speakers that could lead to language learning.

Probability_of_Contact_with_Native_Non_Speakers =
Native_Language_Non_Speakers/Native_Population
UNITS: dmnl
DOCUMENT: Likelihood of contact between speakers and non-speakers.

Relative_Native_Speakers =
Native_Language_Speakers/Native_Language_Speakers_Initial_Value_2002
UNITS: dmnl
DOCUMENT: The relative measure of native language speakers compared to the baseline number of speakers in 2002.

Time_Practicing_at_Home_with_Family = 10.5
UNITS: Hours/Weeks
DOCUMENT: The average time spent practicing the native language with family members, differing between same- and mixed-ethnicity households but due to limitations, the average was used, based on stakeholders' experience.

****

Language_Utility:

****

Base_Utility_of_Native_Language = 1

UNITS: dmnl

DOCUMENT: The default or initial utility value of the native language before external factors are applied.

Change_in_Economic_Opportunities = Economic_Opportunities_Favoring_Major_Language*Economic_Opportunity_Growth_Rate

UNITS: 1/Years

DOCUMENT: The rate at which economic opportunities grow or decline over time, influenced by a specified growth rate and bounded by a base level.

Change_in_Perceived_Utility = -1*(Current_Utility-Perceived_Utility_of_Native_Language)/Time_to_adjust_the_Perceived_Utility

UNITS: 1/Years

DOCUMENT: The rate of adjustment of perceived utility of the native language, based on the difference between current utility and perceived utility. The adjustment happens over a defined time period.

Current_Utility = Utility_of_Native_Language/Base_Utility_of_Native_Language

UNITS: dmnl

DOCUMENT: The adjusted utility of the native language, accounting for changes due to economic opportunities.

Economic_Opportunities_Favoring_Major_Language(t) = Economic_Opportunities_Favoring_Major_Language(t - dt) + (Change_in_Economic_Opportunities) * dt {NON-NEGATIVE}

INIT Economic_Opportunities_Favoring_Major_Language = 1

UNITS: dmnl

DOCUMENT: Represents the degree to which economic opportunities favor a major language (Russian language), negatively influencing the utility of the native language.

Economic_Opportunity_Growth_Rate = 0.02

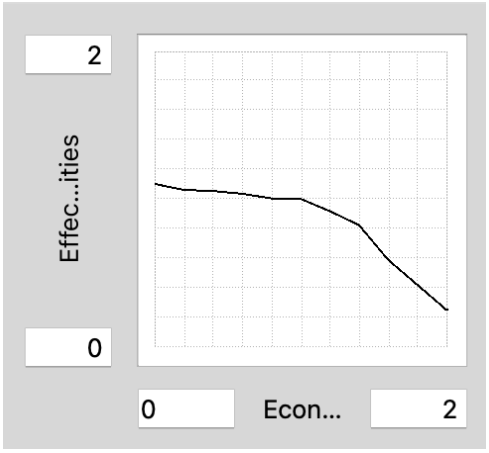
UNITS: 1/Years

DOCUMENT: This constant represents the annual growth rate of economic opportunities favoring the dominant language (e.g., Russian) over the native language, influencing language use and perceived utility. Economic opportunities favoring the Russian language are represented on a scale from 1 to 10 and showing a stable annual growth of 0.02 which is a direct influence on the perceived utility of Kabardian. The broader economic trends are not included.

Effect_of_Economic_Opportunities GRAPH(Economic_Opportunities_Favoring_Major_Language)

Points: (0.000, 1.084), (0.200, 1.028), (0.400, 0.972), (0.600, 0.849), (0.800, 0.726), (1.000, 0.648), (1.200, 0.547), (1.400, 0.480), (1.600, 0.425), (1.800, 0.346), (2.000, 0.246)

UNITS: dmnl



DOCUMENT: his function models how increasing economic opportunities for the dominant language reduce the utility of the native language.
Low Pressure (0.000, 1.084): When economic opportunities are balanced, the native language utility remains high.
Moderate Pressure (1.000, 1.000): Utility decreases significantly, reflecting economic incentives to shift toward the dominant language.
High Pressure (2.000, 0.246): The native language becomes nearly obsolete in response to overwhelming economic forces.

Initial_Perceived_Utility = 1
UNITS: dmnl
DOCUMENT: The initial perceived utility of the native language at the start of the simulation.

Perceived_Utility_of_Native_Language(t) = Perceived_Utility_of_Native_Language(t - dt) + (-Change_in_Perceived_Utility) * dt {NON-NEGATIVE}
INIT Perceived_Utility_of_Native_Language = Initial_Perceived_Utility
UNITS: dmnl
DOCUMENT: How people perceive the usefulness of the native language over time. The perception adjusts based on changes in economic opportunities and other influencing factors.

Time_to_adjust_the_Perceived_Utility = 1
UNITS: Years
DOCUMENT: The time required for perceived utility to align with current utility. This assumes the perception adjusts every year.

Utility_of_Native_Language = Effect_of_Economic_Opportunities*Relative_Native_Speakers
UNITS: dmnl
DOCUMENT: The base or inherent utility of the native language, without accounting for external economic influences.

****
Population_Sector:
****
Birth_Rate = Native_Population*Fractional_Birth_Rate
UNITS: People/Years
DOCUMENT: The number of people added to the native population annually based on the fractional birth rate.

Death_Rate = Native_Population*Fractional_Death_Rate
UNITS: People/Years
DOCUMENT: The number of people subtracted from the native population annually based on the fractional death rate.

Fractional_Birth_Rate = 0.115
   UNITS: 1/year
   DOCUMENT: Birth rate as a fraction of the population.

Moi gorod. Kabardino-Balkaria. Statistica. *[My City. Kabardino-Balkaria. Statistics.]* (n.d.). Retrieved from https://www.mojgorod.ru/kabardbalk_r/statS0.html

Fractional_Death_Rate = 0.098
   UNITS: 1/year
   DOCUMENT: Death rate as a fraction of the population.

Moi gorod. Kabardino-Balkaria. Statistica. *[My City. Kabardino-Balkaria. Statistics.]* (n.d.). Retrieved from https://www.mojgorod.ru/kabardbalk_r/statS0.html

Native_Population(t) = Native_Population(t - dt) + (Birth_Rate - Death_Rate) * dt {NON-NEGATIVE}
   INIT Native_Population = Native_Population_Initial_Value_2002
   UNITS: People
   DOCUMENT: The total number of people in the community, including both native speakers and non-speakers. It grows based on the birth rate and decreases with the death rate.

Native_Population_Initial_Value_2002 = 519958
   UNITS: People
   DOCUMENT: The number of people who identified themselves as Kabardians in 2002 during the Russian Federation Population Census.

Federal State Statistics Service. (2002). Itogi Vserossiyskoy perepisi naseleniya 2002 goda [Results of the All-Russian Population Census 2002]. Retrieved from http://www.perepis2002.ru/index.html?id=17

Extreme Conditions Test Results

Learning Fraction

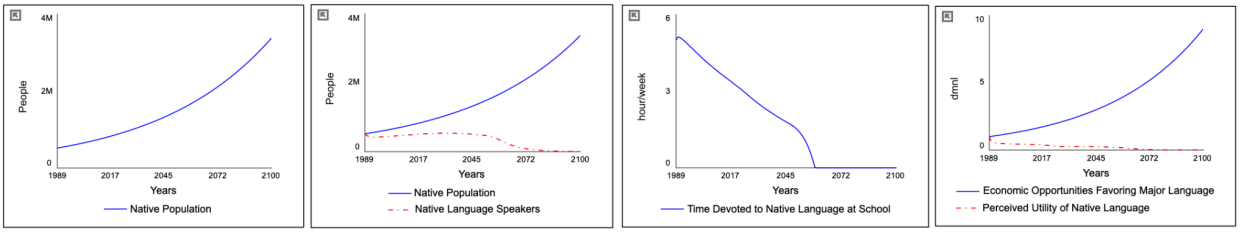


Figure 9. Learning Fraction = 0.02 - Base Run

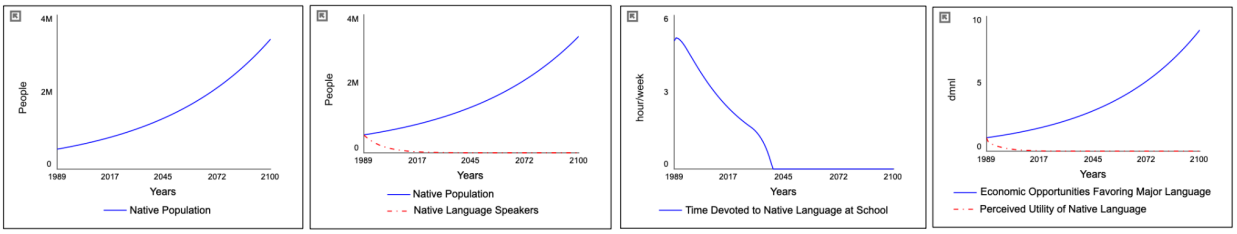


Figure 10. Learning Fraction = 0 - Min Value

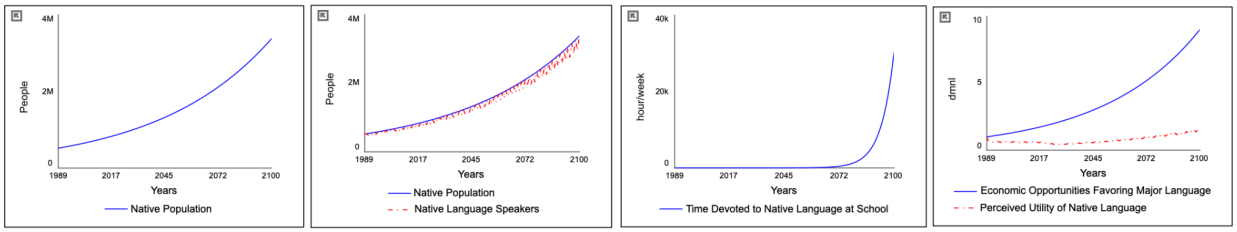


Figure 11. Learning Fraction = 1 - Max Value

Contact Rate

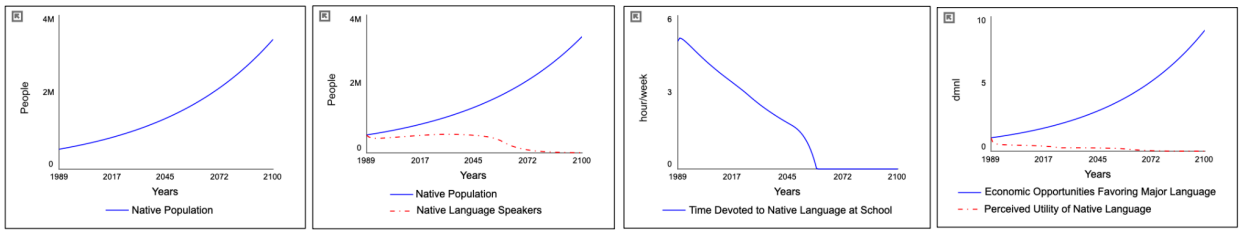


Figure 12. Contact Rate = 65 - Base Run

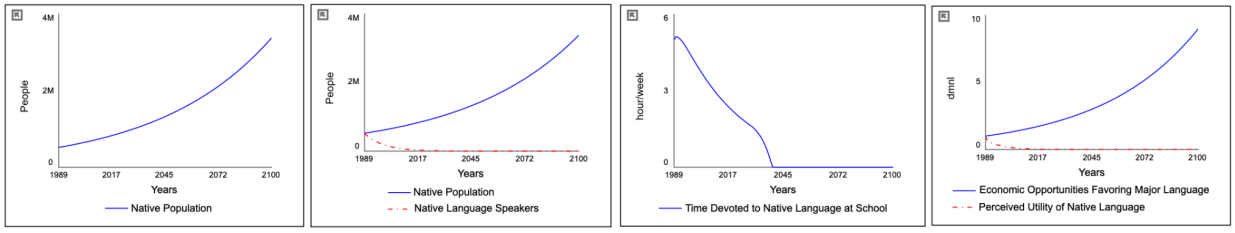


Figure 13. Contact Rate = 0 - Min Value

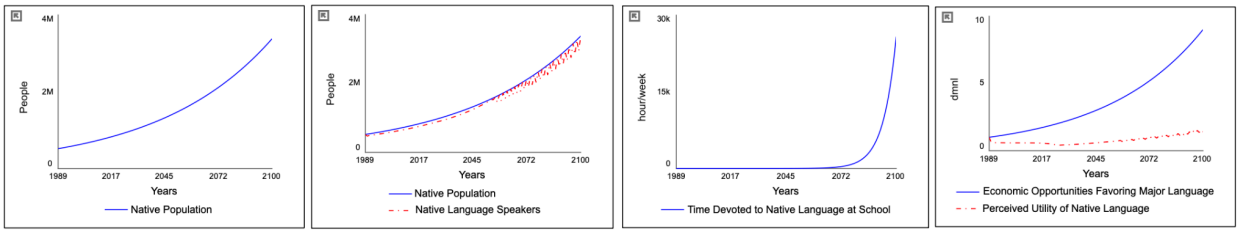


Figure 14. Contact Rate = 200 - Max Value