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Stochastic Model for Language Extinction Dynamics of Hausa Against Kanuri in Nigeria

SALIHU HAUWA DANJUMA[1], AKINREFON ADESUPO ADEOYE[2], SAIDU SAUTA ABDULKADIR[3], JIBASEN DANJUMA[4]
[1]*Department of Mathematics and Statistics, Federal University Kashere, Nigeria*
[2, 3, 4]*Department of Statistics, Modibbo Adama University, Yola, Nigeria*

Abstract- ***Language shift and weakening intergenerational transmission pose important challenges for indigenous languages in multilingual societies. This paper assesses Kanuri vulnerability under Hausa influence using questionnaire data and complementary stochastic models. The study uses 386 respondents and examines language competence, reported reasons for non-transmission, Poisson/branching-process estimates, an absorbing Markov chain, and a survey-based SIR proxy. Hausa reported competence was 97.96% speaking, 93.20% reading and 94.56% writing, while Kanuri reported 75.22%, 60.53% and 58.77%, respectively. Kanuri first-generation transmission probability was 0.699 compared with 0.853 for Hausa. The Markov analysis gave expected persistence of 3.325 generations for Kanuri and 6.825 for Hausa under the first-generation estimates. The survey-based SIR proxy for Kanuri was 4.297 in the first generation and 2.537 in the second. The findings consistently indicate greater vulnerability of Kanuri to weakening intergenerational transmission than Hausa in the observed sample. The results support strengthening parent-to-child transmission, Kanuri literacy, education, media and community use. The mathematical values are model-based and survey-based indicators, not guaranteed population-wide extinction.***

Keywords- ***Language shift; Stochastic process; intergenerational-transmission; Branching process; SIR model.***

I. INTRODUCTION

Language is a complex and dynamic system of communication through which members of community express and exchange ideas, emotions, intentions, knowledge and experiences. It consists of conventional symbols and grammatical rules that are socially shared, acquired through interaction, transmitted across generations and capable of changing over time. Contemporary linguist perspectives therefore view language not merely as collection of words or sounds, but as socially embedded system that depends on its speakers and their continued use and transmission of the language within a community [14,17] Human languages are characterized by cultural and historical diversity, with significant variations observed between cultures across time [13]. The origin of Language, its relationship with human evolution, and its consequences have been subjects of study for centuries [18]. Human languages possess the properties of productivity and displacement, enabling the creation of an infinite number of sentences, the ability to refer to objects, events and ideas. The number of human languages in the world vary between 5,000 and 7,000. Precise estimates depend on arbitrary distinction established between languages and dialects [8].

The world language system is undergoing rapid change because of demographic trends, new technology and international communication. These changes affect both written and spoken communication. Academic census holds that between 50% and 90% of languages spoken at the beginning of the 21st century will probably become extinct by year 2100[2]. Language extinction may be understood at several levels. At the speaker-population level, extinction occurs when the number of effective speakers reaches zero or falls below a practically meaningful threshold. At the family level, extinction can occur when parents no longer transmit the language to children. At the community level, extinction may occur when the language ceases to be used in ordinary social domains even if a small number of older speakers retain competence [3]. A study of Ngizim in Yobe State reported a pronounced shift toward Hausa among younger age groups, identifying the dominant regional language as a major pressure on the minority language [13]. Although Ngizim is not

Kanuri, the study is directly relevant because it demonstrates the type of regional language-contact mechanism that a Kanuri-Hausa model needs to capture. A study of the Khaddamari community in Jere Local Government Area of Borno State reported that Kanuri, the indigenous language of the community, was increasingly giving way to other local languages, particularly Hausa, with the trend more visible among younger people. The study associated the change with changing preferences and the perceived social attractiveness of Hausa among younger speakers. This evidence supports treating Hausa exposure as a potentially important transition pressure in a Kanuri-Hausa model, while also demonstrating why the model should allow the strength of the pressure to vary across age groups and social contexts [4].

[1] modelled language death as competition between two languages and showed how differences in language status and speaker populations can produce dominance of one language and decline of another, providing a foundational mathematical basis for language-extinction modelling.[12] analysed the frequency of convergence to each of the equilibrium points defined by an intervention threshold and found that accounting for local social-network effects made language coexistence more difficult to sustain than a simple competition analysis would suggest.[16] extended the competition framework with spatial dependence and demonstrated that geographical separation can support the coexistence of competing languages.

[5] conceptualised indigenous language transmission as a Poisson process and used the model to study language extinction in Nigeria, estimating intergenerational transmission probabilities from survey evidence and finding declining transmission probabilities for some indigenous languages an important Nigerian foundation for stochastic language modelling

There is mostly sparse literature in existing studies on Language extinction using stochastic differential equations with the combination multiple factors associated with language extinction although substantial progress has been made in deterministic models and empirical studies have demonstrated that language extinction is rarely caused by single factor rather it results from interactions among different factors .Some of this literature include [6] demonstrated that a stochastic SIR formulation could be used to estimate a basic reproduction-type quantity, a threshold of endemicity and expected time to language extinction. Their approach is especially relevant because it explicitly incorporates non-homogeneous mixing and family-level subcommunities. The later absorbing Markov-chain model provides a complementary generational perspective by treating language ability as a discrete state and studying the probability of eventual absorption[7]. The two approaches can therefore be viewed as modelling different time scales of the same phenomenon: the Markov chain focuses on generation-to-generation transmission, while SIR/SDE models focus on continuous-time population dynamics

[6]demonstrated the applicability of the Susceptible-Infectious-Removed framework to indigenous-language extinction using Nigerian survey and demographic information. The present study extends this theoretical framework by introducing multi-populations and stochastic effects.

A Kanuri-speaking individual is considered susceptible when continued interaction with Hausa creates an opportunity for language shift; Hausa-speaking individuals are treated as infectious when their linguistic behaviour, social influence or interaction with susceptible speakers generates a transition toward Hausa. The proposed analogy permits the mathematical formulation of branching processes, absorbing Markov chains, SIR models and stochastic differential equations to be used while yet retaining the sociolinguistic meaning of language acquisition and shift.

II. DERIVIATION OF THE METHODS

In this section, we develop a stochastic differential model to describe the SIR dynamics of Kanuri under the influence of Hausa. The language interpretation follows) [1] and [6], while the stochastic calculus follows [15]We let S(t) denote number of Kanuri speakers at time t, I(t) represent n umber of Hausa dominant speakers and R(t) represent number of permanent shifted speakers. In the absence of Hausa in

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the population the Kanuri population grows at a constant rate recruitment rate.

To account for environmental and social variability, we incorporate independent standard wiener process W_i(t) with noise intensities $\sigma_i(1,2,3)$. The resulting system of Stochastic differential equation are:

$$\begin{cases} \mathrm{dS} = \left(\Lambda - \beta\frac{SI}{N} - \mu S\right)dt + \sigma_1 S dW_1(t) \\ dI = \left(\beta\frac{SI}{N} - (\Upsilon + \mu)I\right)\mathrm{dt} + \sigma_2 I dW_2(\mathrm{t}) \\ \mathrm{dR} = (\Upsilon I - \mu R)\mathrm{dt} + \sigma_3 R d\, W_3(\mathrm{t}) \end{cases} \quad (1)$$

With initial condition $S_0 \geq 0$, $I_o \geq 0$, $R_o \geq 0$

We assumed that all parameters that all the parameters in the model (1) are positive and are summarized in Table 1. Table 1.Description of model parameters

β – Transmission rate from Kanuri to Hausa

Λ –constant recruitment rate of Kanuri speakers

Υ –Transition from influent to stable Hausa speaker (I-R)

μ –Natural exist

$\sigma_{1,2,3}$ –Noise intensities

III. ANALYSIS OF BASIC PROPERTIES OF THE MODEL

3.1 EXISTENCE AND UNIQUENESS OF GLOBAL POSITIVE SOLUTION

To examine the dynamic behavior of the population system we seek to establish the global existence and positivity solution of the system of equation (1)

Lemma 3.1: Given any initial values S(0),I(0),R(0) $\in \mathbb{R}^3$ the system of equation has a unique positive local solution.

Theorem 3.1 Assume $\Lambda, \beta, \Upsilon, \mu \geq 0$, positive initial values, and the standard local-Lipschitz and linear-growth conditions for the diffusion coefficients. Then the stochastic system (1) admits a unique global strong solution which remains non-negative; with positive initial conditions and multiplicative environmental noise, the compartments remain positive on finite intervals almost surely.

Proof,

On every compact subset of $D = \{x \in {R_+}^3 : x_1 + x_2 + x_3 > 0\}$, $N = x_1 + x_2 + x_3$ is bounded away from zero. Hence $\beta x_1 x_2 / N$ is continuously differentiable and locally Lipschitz. The drift and diffusion coefficients are therefore locally Lipschitz, so the standard SDE existence-uniqueness theorem gives a unique local strong solution.

For positivity, apply Itô's formula to ln S(t) before the first possible hitting time of zero:

The stochastic exponential generated by the multiplicative noise is strictly positive and $\Lambda/S(t) \geq 0$. Thus S(t) cannot cross zero from a positive initial value. The same integrating-factor argument applies to I(t) and R(t).

3.2 Stochastic Ultimate Boundedness

Theorem 3.2. The solution (S(t),I(t),R(t)) of system (2) is stochastically ultimately bounded for any initial value in $\mathbb{R}^3_+$.

Proof

Define the total population by

$$V(t) = \Sigma_{\mathrm{k}=1}{}^{\mathrm{n}}[S_k(t) + I_k(t) + R_k(t)] \quad (6)$$

Adding the three equations for each population cancels the transmission and I→R terms. Under conservative migration, internal migration terms cancel after summation over k. Hence

$$dV(t) \leq [\Lambda - \mu V(t)]dt + dM(t) \quad (7)$$

where M(t) is a local martingale. Taking expectations gives

$m'(t) \leq \Lambda - \mu^* m(t)$, $m(t) = E[V(t)]$.

Multiplying by $e^{\{\mu * t\}}$ and integrating from 0 to t yields

$$E[V(t)] \leq V(0)e^{\{-\mu * t\}} + \frac{\Lambda}{\mu^*}(1 - e^{\{-\mu * t\}}).$$

Thus $sup_\{t \geq 0\}E[V(t)] < \infty$. The stopping-time argument for the level sets of V then gives zero explosion probability on every finite interval. Hence the system is bounded in expectation and non-explosive.

3.3 Stochastic Persistence

Theorem 3.3 (Stochastic persistence)

If the long-run logarithmic growth rate of I(t) at the extinction boundary is bounded below by $\varepsilon > 0$, and the process is tight and irreducible in the interior, then I(t) is stochastically persistent. $R_o{}^s$>1 is a threshold indicator, but by itself does not prove persistence for the full stochastic system.

Proof

From (3.5), the logarithmic drift near I=0 is $\beta S/N - (\gamma + \mu) - \sigma^2 I, e/2$. If its long-run average is at least $\varepsilon > 0$, the Brownian term has asymptotically zero average and logarithmic growth remains positive near the boundary. Hence the process cannot spend asymptotically all its time near I=0. Tightness prevents escape to infinity and irreducibility permits return to interior sets, giving stochastic persistence.

3.4 Ergodicity of the System

Theorem 3.4 (Invariant distribution and ergodicity)

Suppose the process is Feller and there is a coercive Lyapunov function V≥1 satisfying

together with an appropriate irreducibility/petite-set condition. Then an invariant probability distribution exists; under the corresponding Harris recurrence condition it is unique and the process is ergodic.

Proof

For $\tau R = inf\{t \geq 0: V(Xt) \geq R\}$, Dynkin's formula gives

$E[V(X(t \wedge \tau R))] = V(X_0) +$

$E \int_0^{(t \wedge \tau R)} \mathcal{L}V(Xs)ds$

$\leq V(X_0) - cE[t \wedge \tau R] + dE[t \wedge \tau R]$

The drift inequality controls occupation outside sufficiently large compact sets and yields tightness of the empirical measures $\Pi T = (1/T) \int_0^T Law(Xt)dt$. By the Krylov–Bogoliubov argument, a weak limit is invariant. The additional irreducibility/Harris condition gives uniqueness and ergodicity

3.5 Stochastic Reproduction Number

Using the next-generation method,

$R_0 = \rho(FV^{-1})$ (9)

For the Hausa-influence compartment, the new-influence rate is $\beta S/N$ and the removal rate is $\Upsilon + \mu$. At the disease-free equilibrium $S* = N*$,

$$R_0 = \frac{\beta}{\Upsilon + \mu}$$

For multiplicative stochastic perturbation in I, Itô's gives the stochastic threshold

$$R_0{}^s = \frac{\beta}{\Upsilon + \mu + \sigma^2 I, e/2}$$

3.6 Stochastic Extinction of Hausa Influence

Theorem 3.2 (Stochastic extinction)

If $\beta - (\gamma + \mu) - \sigma^2 I, e/2 < 0$, equivalently $R_0{}^s < 1$ under (3.5), then I(t)→0 almost surely as t→∞.

Proof

For I(t)>0, Itô's formula gives

$d\ ln\ I(t) = [\frac{\beta S(t)}{N(t)} - (\gamma + \mu) - \frac{\sigma^2 I, e}{2}]dt +$

$\sigma I, e\ dWI, e(t)$

Since $S(t)/N(t) \leq 1$, define $c = (\gamma + \mu) + \sigma^2 I, e/2 - \beta > 0$.

Then $d\ ln\ I(t) \leq -c\ dt + \sigma I, e\ dWI, e(t)$

Integrating and dividing by t gives

$ln\ I(t) \leq ln\ I(0) - ct\sigma I, eWI, e(t)$

$$\frac{ln\ I(t)}{t} \leq \frac{\ln I(0)}{t} - c\sigma I, e \frac{WI, e(t)}{t} \quad (10)$$

Since $W(t)/t \to 0$ almost surely,

$limsup(t \to \infty)\ \frac{ln\ I(t)}{t} \leq -c < 0$

$lim(t \to \infty)\ I(t) = 0\ \ almost\ surely$

IV. NUMERICAL RESULTS

(8)

This present discusses the results obtained from the questionnaire data analysis. This covers demographic characteristics, indigenous-language competence and use, reported reasons for intergenerational non-transmission, Poisson/branching-process estimates an absorbing Markov-chain formulation and survey-based SIR proxy. The results are interpreted jointly because each model captures a different component of language transmission: the Poisson formulation describes the production and transmission of language-speaking offspring; the Markov chain describes persistence across generations and the SIR framework translates transmission information into a reproduction-number and extinction perspective.

The questionnaire provides adequate information for survey-based transmission measures and the generational Markov analysis, consequently, the SIR quantities reported here are explicitly treated as survey-based proxies rather than direct demographic estimates

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Table 1 Overall Demographic characteristics

Indicator	Mean	SD
Age (years)	34.361	13.096
Age at marriage (years)	22.908	4.808
Parents' children	11.159	6.234
Respondent's own children	4.608	3.478
Speak indigenous language (%)	89.034	
Read indigenous language (%)	76.562	
Write indigenous language (%)	74.479	

Table 2 Demographic and language competence indicators by language group

Language group	Understand	Speak	Read	Write
Fulani/Fulfulde	100.00	94.12	72.55	66.67
Hausa	98.46	97.96	93.20	94.56
Kanuri	82.80	75.22	60.53	58.77
Mandara	100.00	100.00	100.00	100.00
Nupe	100.00	100.00	0.00	0.00
Other	95.83	87.23	72.34	57.45
Shuwa Arab	100.00	91.30	69.57	78.26

Tabe 3 Sex composition by language group

Language group	Female	Male	Male:Female ratio
Fulani/Fulfulde	16	35	2.188
Hausa	108	38	0.352
Kanuri	55	60	1.091
Mandara	0	1	—
Nupe	1	0	0.000
Other	10	37	3.700
Shuwa Arab	10	13	1.300

Table 4 Mean age at marriage by language group and sex

Language group	Sex	Mean age	SE	N
Fulani/Fulfulde	Female	20.500	0.842	16
Fulani/Fulfulde	Male	27.538	0.806	26
Hausa	Female	19.961	0.111	103
Hausa	Male	26.833	0.842	24
Kanuri	Female	20.692	0.533	39
Kanuri	Male	27.053	0.686	38
Other	Female	19.000	3.140	7
Other	Male	25.200	1.209	20
Shuwa Arab	Female	22.250	1.740	8
Shuwa Arab	Male	26.700	1.700	10
Total	Female	20.264	0.214	174
Total	Male	26.798	0.411	19

Table 5 indigenous language ability

Language group	Understand	Speak	Read	Write
Fulani/Fulfulde	100.00	94.12	72.55	66.67
Hausa	98.46	97.96	93.20	94.56
Kanuri	82.80	75.2	60.5	58.7
Mandara	100.00	100	100	100
Nupe	100.00	100.	0.00	0.00
Other	95.83	87.2	72.3	57.4
Shuwa Arab	100.00	91.3	69.5	78.2

Table 6 Proportion reporting language inability (%)

Language group	Don't speak	Can't read	Can't write	Don't understand
Fulani/Fulfulde	5.88	27.45	33.33	0.00
Hausa	2.04	6.80	5.44	1.54
Kanuri	24.78	39.47	41.23	17.20
Mandara	0.00	0.00	0.00	0.00
Nupe	0.00	100.00	100.00	0.00
Other	12.77	27.66	42.55	4.17
Shuwa Arab	8.70	30.44	21.74	0.00

Table 7 Reasons for Lack of Intergenerational Transmission

Language	Main Reported Reason	Ni	N	%
Fulani/Fulfulde	Parents unable to speak language	27	43	62.79
Hausa	Parents unable to speak language	118	139	84.89
Kanuri	Parents unable to speak language	51	110	46.36
Other	Parents unable to speak language	19	31	61.29

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Language	Main Reported Reason	Ni	N	%
Shuwa Arab	Parents unable to speak language	20	20	100.00
Mandara	Negligence of parents	1	1	100.00
Nupe	Negligence of parents	1	1	100.00

Table 8 Branching-process estimates of language ransmission

Language group	Gen.1 mean offspring	Gen.1 language offspring	p_1	q_1	Gen.2 mean offspring	Gen.2 language offspring	p_2	q
Fulani/Fulfulde	12.660	40.025	0.752	0.000	5.051	19.208	0.924	0.0
Hausa	10.425	22.536	0.853	0.000	3.712	2.723	0.973	0.0
Kanuri	11.416	53.317	0.699	0.000	5.563	20.049	0.757	0.0
Mandara	17.000	3.000	0.176	0.060	2.000	0.000	1.000	—
Nupe	17.000	8.000	0.471	0.000	5.000	1.000	0.200	—
Other	12.318	56.362	0.646	0.000	5.400	19.833	0.971	0.0
Shuwa Arab	8.455	23.879	0.823	0.001	5.188	13.496	0.884	0.0
Total	11.159	38.863	0.758	0.000	4.608	12.095	0.891	0.0

$q = Extinction\ Probability;\quad p = Transmission\ probabilities$

Table 9: Poisson mean-variance diagnostic

Language	N	Mean	Variance	Variance/Mean
Fulani/Fulfulde	50	12.660	40.025	**3.162**
Hausa	146	10.425	22.536	**2.162**
Kanuri	113	11.416	53.317	**4.670**
Other	44	12.318	56.362	**4.575**
Shuwa Arab	22	8.455	23.879	**2.824**

Table 10 Absorbing markov-chain transmission and persistence estimates

Language	p_1	p_2	Absorption$_1$	Absorption$_2$	Expected Generations$_1$	Expected Generations$_2$
Fulani/Fulfulde	0.752	0.924	1.000	1.000	4.032	13.133
Hausa	0.853	0.973	1.000	1.000	6.825	37.270
Kanuri	0.699	0.757	1.000	1.000	3.325	4.115
Mandara	0.176	0.000	1.000	1.000	1.214	1.000
Nupe	0.471	0.200	1.000	1.000	1.889	1.250
Other	0.646	0.971	1.000	1.000	2.824	34.043
Shuwa Arab	0.823	0.884	1.000	1.000	5.636	8.656
Total	0.758	0.891	1.000	1.000	4.139	9.154

Table 11: Derived SIR threshold and extinction-relatedquantities

Language group / generation	R0 proxy	q_1	τn	τ0
Fulani/Fulfulde – First	5.276	0.022	876.715	4547.854
Hausa – First	5.176	0.029	703.687	3650.288
Kanuri – First	4.297	0.033	584.577	3032.420
Mandara – First	1.333	0.095	175.726	911.557
Nupe – First	4.444	0.016	1187.589	6160.473
Other – First	4.364	0.029	678.620	3520.259
Shuwa Arab – First	3.568	0.058	325.539	1688.692
Fulani/Fulfulde Second	2.493	0.114	165.758	859.851
Hausa – Second	2.361	0.133	153.750	797.558
Kanuri – Second	2.537	0.097	199.313	1033.910
Other – Second	2.733	0.105	184.764	958.440
Shuwa Arab – Second	2.398	0.117	162.080	840.772

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Table 12: Survey-based SIR reproduction-number proxies

Language group	Generation	M	P	Marriage age	Infectious period	R0 proxy	R0ε proxy
Fulani/Fulfulde	First	12.660	0.752	24.857	29.143	5.276	5.798
Hausa	First	10.425	0.853	21.250	32.750	5.176	5.689
Kanuri	First	11.416	0.699	23.831	30.169	4.297	4.722
Mandara	First	17.000	0.176	30.000	24.000	1.333	1.465
Nupe	First	17.000	0.471	24.000	30.000	4.444	4.884
Other	First	12.318	0.646	23.593	30.407	4.364	4.796
Shuwa Arab	First	8.455	0.823	24.722	29.278	3.568	3.921
Fulani/Fulfulde	Second	5.051	0.924	24.857	29.143	2.493	2.740
Hausa	Second	3.712	0.973	21.250	32.750	2.361	2.595
Kanuri	Second	5.563	0.757	23.831	30.169	2.537	2.789
Mandara	Second	2.000	0.000	30.000	24.000	0.000	0.000
Nupe	Second	5.000	0.200	24.000	30.000	0.556	0.611
Other	Second	5.400	0.971	23.593	30.407	2.733	3.003
Shuwa Arab	Second	5.188	0.884	24.722	29.278	2.398	2.635

IV. RESULT AND DISCUSSION

From table 1 Language competence was generally strongest for speaking. Overall, 89.03% of respondents reported that they could speak the relevant indigenous language, compared with 76.56% who could read and 74.48% who could write it. The decline from oral competence to literacy competence suggests that language maintenance is not necessarily uniform across domains. A language may remain actively spoken while its written transmission is comparatively weaker. This distinction is particularly relevant when language vitality is evaluated: continued speaking can sustain everyday communication, whereas limited reading and writing may constrain institutional, educational and intergenerational reinforcement

In table 2 marked heterogeneity is evident across language groups Hausa displayed particularly high reported competence, with approximately 98.0% speaking, 93.2% reading and 94.6% writing the language. By contrast, Kanuri showed a notable reduction across the three domains: 75.2% could speak, 60.5% could read and 58.8% could write. This pattern indicates that Kanuri has a substantially weaker competence profile than Hausa in the observed sample, especially in literacy.Fulani/Fulfulde maintained high oral competence (94.1%) but lower reading (72.5%) and writing (66.7%). Shuwa Arab also showed strong speaking ability (91.3%) but lower reading ability (69.6%). The very small Mandara and Nupe samples should not be used for substantive population-level conclusions because each contains only one respondent.

In table 3 the sex distribution varies considerably by language group. Hausa respondents were predominantly female, whereas Fulani/Fulfulde and Other language groups were predominantly male. Kanuri was comparatively balanced. These differences matter because language transmission may be influenced by the distribution of caregiving, household communication and parent-child interaction, although the present analysis does not estimate a causal sex effect on transmission.

In table 4 across the observed sample, women married at a substantially younger mean age than men (20.26 versus 26.80 years). This gap is visible in the major language groups. For example, Hausa women had a mean marriage age of 19.96 years compared with 26.83 years for Hausa men. Kanuri showed a similar pattern (20.69 years for females versus 27.05 years for males). Because marriage commonly establishes the household context in which parent-child language interaction occurs, these differences provide an important demographic background to the transmission process. However, the present results do not establish that marriage age itself causes language retention or loss.

In table 5 the indigenous language ability results reinforce the conclusion that language vitality is multidimensional. Hausa has the strongest and most balanced competence profile across understanding, speaking, reading and writing. Fulani/Fulfulde and Shuwa Arab also show strong oral maintenance, although literacy is weaker. Kanuri has the largest gap between understanding/speaking and literacy, with only 58.77% reporting writing ability. This may indicate a transition in which oral transmission remains more resilient than formal literacy transmission.

In table 6 the inability results provide a particularly clear indication of differential vulnerability. Kanuri has the highest reported inability in the major language groups: 24.78% cannot speak it, 39.47% cannot read it, 41.23% cannot write it, and 17.20% do not

understand it. In contrast, Hausa has very low inability across all four domains. The contrast suggests that the central language-maintenance challenge is not uniform across the population. Interventions designed to preserve indigenous languages would therefore need to be language-specific rather than assuming that all groups face the same degree of transmission pressure.

In table 7 the reported reasons for non-transmission provide an important explanation for the differences observed in language competence and use. The dominant reason across the principal language groups is that parents are unable to speak their language. This was reported by 84.89% of Hausa respondents in the relevant denominator, 62.79% of Fulani/Fulfulde respondents, 61.29% of the Other group, and 46.36% of Kanuri respondents. For Shuwa Arab, all 20 respondents in the relevant denominator identified parents' inability to speak.

In table 8 the branching-process estimates show that the first-generation transmission probabilities range from 0.176 for Mandara to 0.853 for Hausa among the principal groups. Hausa therefore exhibits the strongest first-generation transmission probability, while Kanuri has a lower value of 0.699 and Fulani/Fulfulde 0.752. The aggregate first-generation probability is 0.758. In the second generation, the total probability rises to 0.891, with Hausa reaching 0.973 and Other reaching 0.971. These estimates should be read as conditional survey-based transmission measures rather than population-wide demographic probabilities the language. The finding suggests that language loss can become self-reinforcing: when parents lose competence, they lose the capacity to provide the next generation with routine exposure to the language. Other reported pressures include inter-tribal marriage, relocation from the state of origin, perceived limitations in schooling, and the influence of civilization and Western culture. These factors should be interpreted as complementary social mechanisms rather than mutually exclusive causes. The extinction probability q is particularly small for most groups in the first generation. This follows mathematically from the estimated branching-process means and indicates that, under the model's assumptions, the language-speaking lineage is not expected to become extinct immediately when transmission remains sufficiently productive. However, the Markov-chain results later in the analysis show eventual absorption when the transmission probability is below one. These findings are not contradictory, rather implying that while a branching process can have a low short-term extinction probability, the a finite-horizon or long-run generational process still tends toward eventual loss.
In table 9 the variance-to-mean ratios exceed one for all language groups with sufficient observations, demonstrating substantial over-dispersion relative to the basic Poisson assumption. The strongest over-dispersion is observed for Kanuri (variance/mean = 4.670), followed by Other (4.575) and Fulani/Fulfulde (3.162). This is an important model-diagnostic finding. Although the Poisson/branching process is useful as a conceptual transmission model, the empirical variability is greater than a simple Poisson process would imply.

In table 10 the absorbing Markov-chain results provide one of the clearest long-run interpretations of the study. Because the estimated transition probabilities are below one, eventual absorption into the language-loss state is predicted with probability one in the model. Thus, even groups with relatively strong current transmission are not mathematically permanent under a fixed transition probability $p < 1$.
The expected persistence horizon differs sharply by language group. In the first-generation estimates, Hausa has the largest expected persistence at 6.825 generations, followed by Shuwa Arab at 5.636 and Fulani/Fulfulde at 4.032. *Kanuri has a much shorter expected persistence of 3.325 generations.* For the second-generation probabilities, Hausa increases dramatically to 37.270 expected generations and Other to 34.043, whereas Kanuri remains low at 4.115. This contrast illustrates why both current transmission and long-run persistence must be examined rather than relying on a single measure of language vitality.

In table 4.11 the derived extinction-related quantities show a consistent pattern: lower reproduction potential is accompanied by a larger immediate extinction-related rate $\dot{q}1$ and shorter characteristic time quantities. For example, the first-generation Shuwa Arab proxy has $R0 = 3.568$ and $\dot{q}1 = 0.058$, compared with Fulani/Fulfulde where $R0 = 5.276$ and $\dot{q}1 = 0.022$. In the second generation, Hausa has $R0 =$

2.361 and $\dot{q}1 = 0.133$, while Fulani/Fulfulde has R0 = 2.493 and $\dot{q}1 = 0.114$. These relationships support the qualitative interpretation that declining transmission increases vulnerability to eventual language extinction.

In table 4.12 the survey-based SIR proxies are greater than one for most first-generation language groups, with the exception of Mandara, whose proxy is 1.333 and therefore remains above one despite very weak estimated transmission. The largest first-generation proxy is observed for Fulani/Fulfulde (5.276), followed by Hausa (5.176), Kanuri (4.297), Other (4.364), Nupe (4.444) and Shuwa Arab (3.568). These values indicate that, under the proxy formulation, the estimated transmission environment is sufficiently strong for continued propagation of language ability in the modeled first generation.

The second-generation proxies decline substantially for most groups. Hausa falls to 2.361, Fulani/Fulfulde to 2.493, Kanuri to 2.537 and Shuwa Arab to 2.398. Nupe falls below the critical value of one (0.556), while Mandara falls to zero. This is consistent with the broader finding that lower generational transmission can rapidly weaken the effective reproduction potential of a language. The epsilon-adjusted proxy is systematically slightly larger than the unadjusted proxy, but the substantive ranking is broadly preserved.

V. CONCLUSION

The study provides an integrated empirical and stochastic assessment of Kanuri to Hausa language dynamics. Across descriptive, branching, Markov and SIR-proxy analyses, Kanuri shows greater vulnerability than Hausa in the observed sample. The evidence points particularly to weaker literacy and intergenerational transmission. The study does not establish a deterministic date of extinction; instead, it identifies measurable vulnerability and provides

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