Clans, Guilds, and Markets: Apprenticeship Institutions and Growth in the Pre-Industrial Economy

David de la Croix[1] Matthias Doepke[2] Joel Mokyr[2]

[1]Univ. cath. Louvain (Belgium)

[2]Northwestern University

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Technological Progress in the Malthusian Era

"Knowledge how" key for functioning of economies

Until 19th century, tacit knowledge (Foray)

Apprenticeship: "stealing with their eyes" (Steffens)

Different modes of apprenticeships: family, clan, guild, market

Aim: analyze apprenticeship as a global phenomenon, organized in different modes

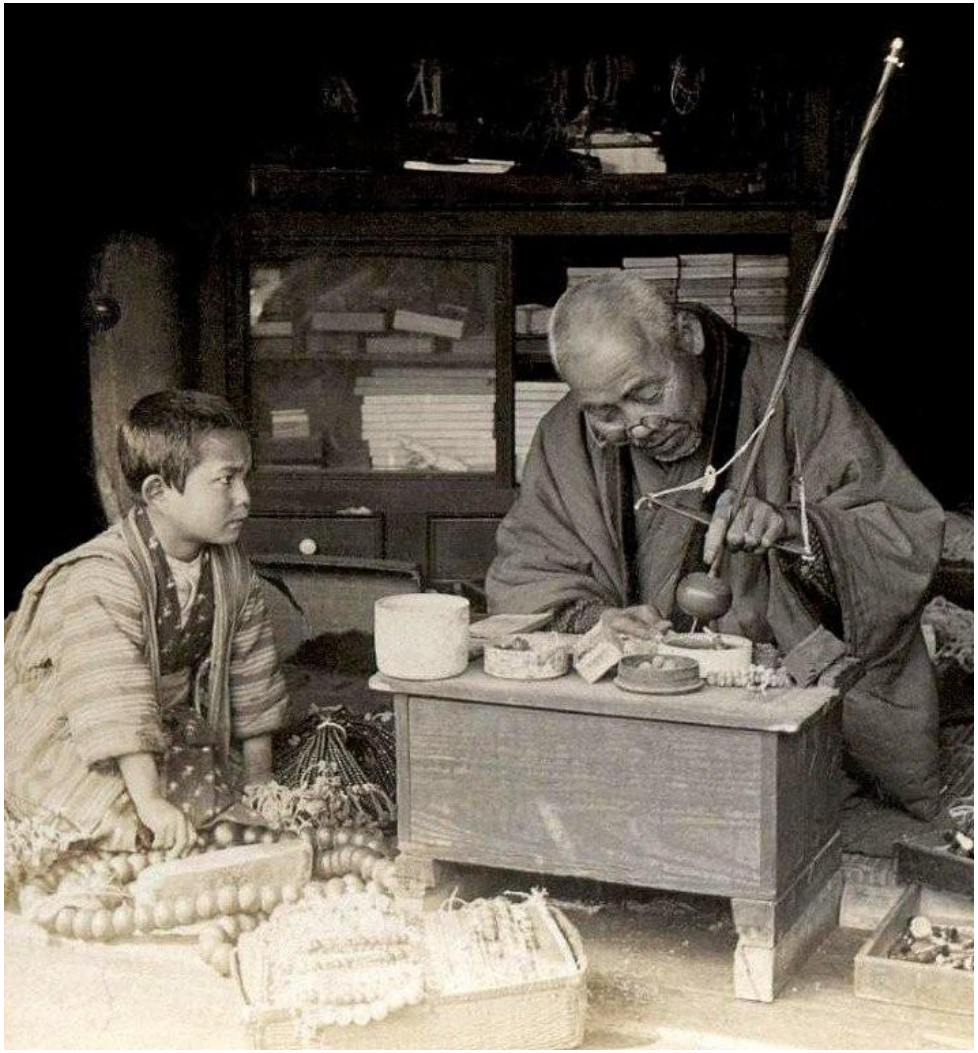
Literature (e.g. Unified growth theory): technological progress out of black box, but key to generate the growth take-off.

young apprentice being taught how to use a pump drill

THE BEAD MAKER

Apprentice Watches the Master

Old Meiji-Era Japan



Why a Special Model for Preindustrial Times?

In existing endogenous growth models, technological progress based on human-capital accumulation through formal schooling or formal R&D activities.

Do not apply to pre-industrial era

Questions a model of apprenticeship can address:

Which mode of knowledge transmission was more complementary to technical progress?

why Western Europe pulled ahead of other regions in terms of technological progress and growth in the centuries leading up to industrialization?

How We Answer the Questions

Build model where children learn from elders, and adopt the best ideas they have been exposed to.

There are four ways in which society can set up apprenticeship to solve the basic moral hazard and contract-enforcement problem:

- The **family** equilibrium in which sons learn only from their fathers.
- A **clan** equilibrium in which apprentices learn from a larger group related by blood (extended family).
- A **guild** equilibrium, in which all artisans are members of a well-defined group of unrelated people.
- A **market** equilibrium with competitive contract enforced by a third part.

Moral hazard

Moral-hazard problem in master-apprentice relationship.

Masters have an incentive to make no effort but take the output of apprentices.

Without enforcing institutions, multiple equilibria, with family-based transmission (Europe) or clan-based transmission (Rest of the world).

Consider incentives for adopting institution to deal with moral-hazard problem: Guild or market.

Show that growth faster with market/guild than with clan, than with family.

Argue that adoption less likely in clan-based system.

Relation to literature

Combine elements from different literatures:

- Malthusian model of income and population (Ashraf and Galor 2011).
- Models of technological progress based on person-to-person transmission of ideas (Lucas 2009, Lucas and Moll 2011, Perla and Tonetti 2014, Alvarez, Buera, and Lucas 2014).
- Contract enforceability and institutional change in economic history (Greif 1993, 1994, Greif and Tabellini 2010).

Typical contract in Europe

Marseilles (c. 1250 CE)

April the ninth. I, Peter Borre, in good faith and without guile, place with you, Peter Feissac, weaver, my son Stephen, for the purpose of learning the trade or craft of weaving, to live at your house, and to do work for you from the feast of Easter next for four continuous years, promising you by this agreement to take care that my son does the said work, and that he will be faithful and trustworthy in all that he does, and that he will neither steal nor take anything away from you, nor flee nor depart from you for any reason, until he has completed his apprenticeship. And I, the said Peter Feissac, promise you, Peter Borre, that I will teach your son faithfully and will provide food and clothing for him. Done at Marseilles, near the tables of the money-changers. Witnesses, etc.

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incomplete contract - moral hazard

Solution to moral hazard

(1) informal institutions, based on reputation and trust (family, extended family & clan);

(2) non-state semi-formal institutions (guilds, local authorities such as the Dutch *neringen*);

(3) third party (state) enforcement usually by local authorities (city) and courts.

coexist, but intensity varies across regions

Different apprenticeship systems

"in China, training was provided by relatives, and hence a narrow group of experts, instead of the much wider training opportunities provided by many European guilds." (Prak and van Zanden, 2013)

In China, guilds were organized along lines of a common origin, rather than a citizenship in the place where the guild was based as in Europe, (Moll-Murata, 2013)

In Europe, number of apprentices who were trained by people related to them was a distinct minority, estimated in London to be somewhere between 7 and 28 percent

Markets work (in England): prices adjust to market conditions, flexible contracts

Guilds

Two views:

- guild-critical: set of rent-seeking clubs, hostile to innovation, limiting membership (Ogilvie)
- guild rehabilitationist: enforced contracts (Epstein)

Rembrandt (1662) - Governors of the Drapers' Guild

Mobility and diffusion

Europe: towns and their guilds acknowledge the skills acquired in other towns (but newcomers had to adapt to standards set by guilds).

"journeyman": after the completion of their training they would travel to another city before they would qualify as masters, to acquire additional skills – much like postdoctoral students today

The best evidence for diffusion: towns that believed to enjoy technological superiority forbade the practice of tramping and made apprentices swear not to practice their trades anywhere else, as happened to Nuremberg metal workers and Venetian glassmakers

Preferences

Overlapping generations of craftsmen (extension with farmers)

Adults make all decisions. Population size: N.

Adult preferences given by utility function:

$$u = c - \delta(a) + \gamma n l',$$

where c is consumption, n is children, l' is child future income, and a is the number of apprentices teached.

Existing knowledge of craftsmen embodied in adult generation.

Future craftsmen acquire knowledge by learning from elders.

Technology

Output produced by competitive industry using land $X = 1$ and effective craftsmen's labor L:

$$Y = (L)^{1-\alpha} X^{\alpha}.$$

craftsmen own land, differ in knowledge, and belong to some trade j.

Different trades j:

$$L = \left(\int_0^1 (L_j)^{\frac{1}{\lambda}} dj \right)^{\lambda}.$$

Knowledge

Own knowledge of craftsman i measured by an individual cost parameter: h_i

Distribution of craftsmen's cost parameter is exponential:

$$h_i \sim \text{Exp}(k).$$

Distribution parameter k measures average efficiency:

$$\text{E}[h_i] = \frac{1}{k}.$$

Craftsmen's Productivity

Effective labor supplied by craftsman i:

$$q_i = h_i^{-\theta}.$$

Expected efficiency:

$$E[q_i] = \int_0^\infty h_i^{-\theta} \left(k \exp(-kh_i)\right) dh_i = k^\theta \Gamma(1-\theta),$$

Total supply of effective craftsmen's labor:

$$L = Nk^\theta \Gamma(1-\theta).$$

Two state variables: $\{N, k\}$

Now, we specify the dynamics of state variables

Population growth:

Every adult gives birth to $\bar{n} > 0$ children; n survive.

Child survival depends on aggregate output per adult Y/N:

$$n = \bar{n} \min[1, sY/N].$$

Acquiring Knowledge

Consider apprentice who learns from m independent elders.

Elders' knowledge can be observed only by working with them. Efficiency of elder i measured by cost parameter h_i.

Apprentices adopt knowledge of most efficient master they have learned from:

$$h_L(m) = \min\{h_1, h_2, \ldots, h_m\}.$$

On reaching adulthood, apprentice also generates new idea with efficiency h_N.

Final efficiency level is:

$$h' = \min\{h_L, h_N\}.$$

Distribution of Knowledge and Efficiency

Distribution of new idea is also exponential, and quality of new ideas depends on average knowledge:

$$h_N \sim \text{Exp}(\nu k).$$

Parameter ν measures relative importance of transmitted knowledge and new ideas.

Learning process preserves shape of knowledge distribution over time:

$$h_L = \min\{h_1, h_2, \ldots, h_m\} \sim \text{Exp}(mk),$$
$$h' = \min\{h_L, h_N\} \sim \text{Exp}(mk + \nu k).$$

Hence, knowledge k evolves according to:

$$k' = (m + \nu)k.$$

Balanced Growth Path

We consider balanced growth path with $g = k'/k$.

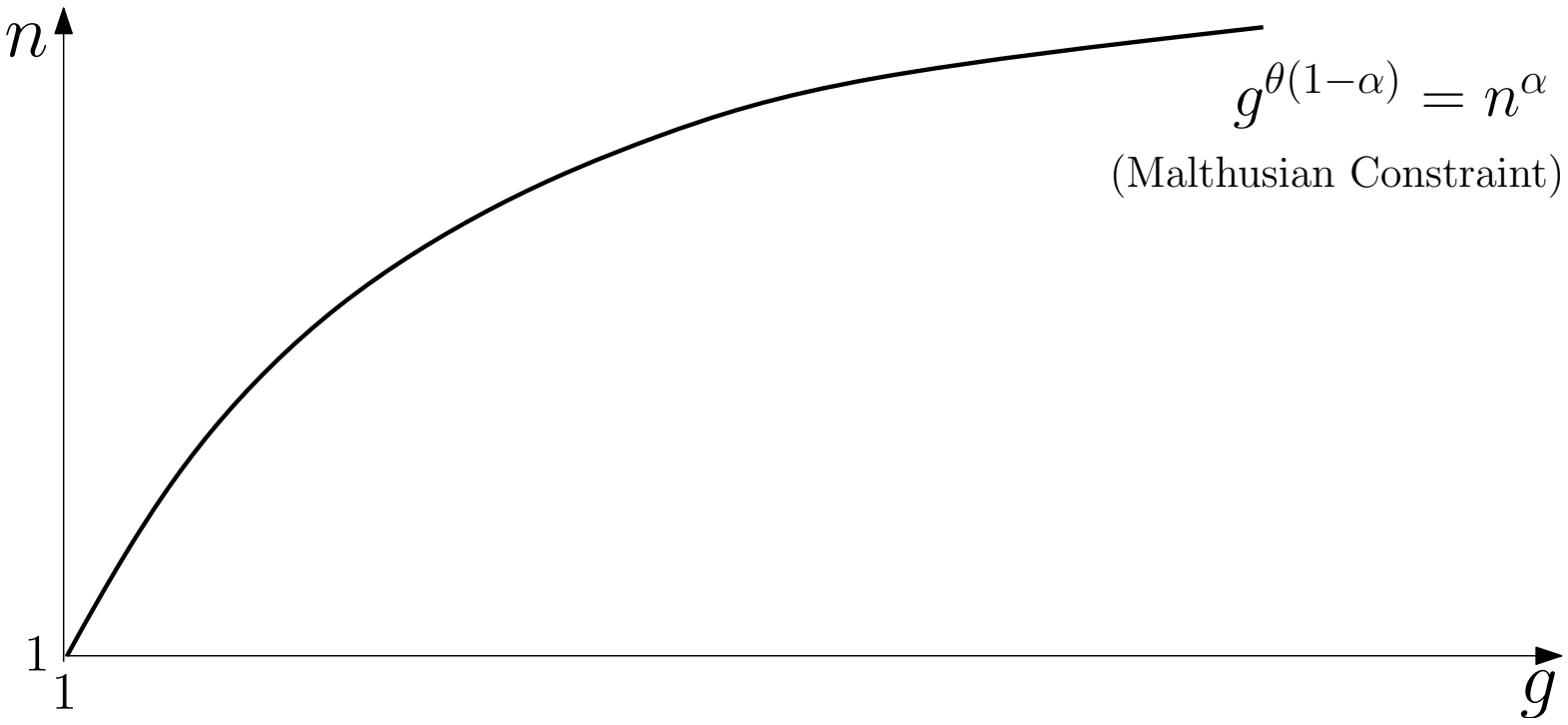
Knowledge accumulation depends on the mode of apprenticeship.

All modes satisfy:

Proposition (The Malthusian Constraint)

Along a balanced growth path, independently of the prevailing apprenticeship system, there is a relation between the growth factor of technology g and the growth factor of population n given by

$$g^{\theta(1-\alpha)} = n^{\alpha}. \tag{1}$$



Faster technological progress makes higher population growth feasible.

Moral hazard and enforcement

When working with an elder, apprentice produces κ.

Elder who teaches a apprentices incurs cost $\delta(a)$ (increasing, convex).

Moral hazard problem: Elder can take on apprentices, keep production κa, but not actually teach, saving cost $\delta(a)$.

Without formal enforcement institutions, adults can inflict utility loss (damage) d on other adults, where $d < \delta(1)$.

Formal institutions can be adopted at some cost (see later).

Family Equilibrium

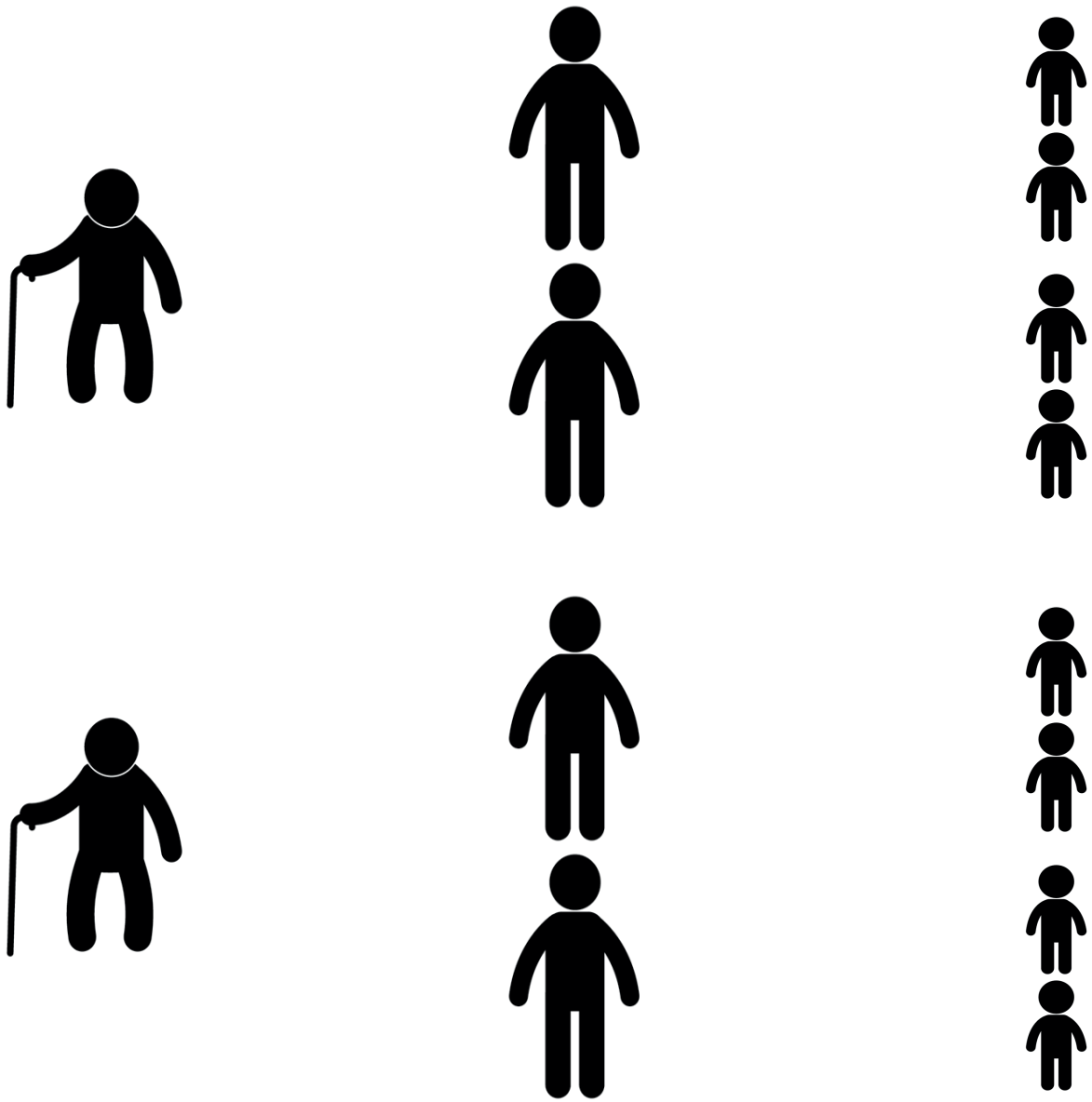
Game between craftsmen of a given generation:

- Decide whether to send own children to others as apprentices for training.
- Decide whether to exploit own apprentices (if any).
- Decide whom to punish (if anyone).

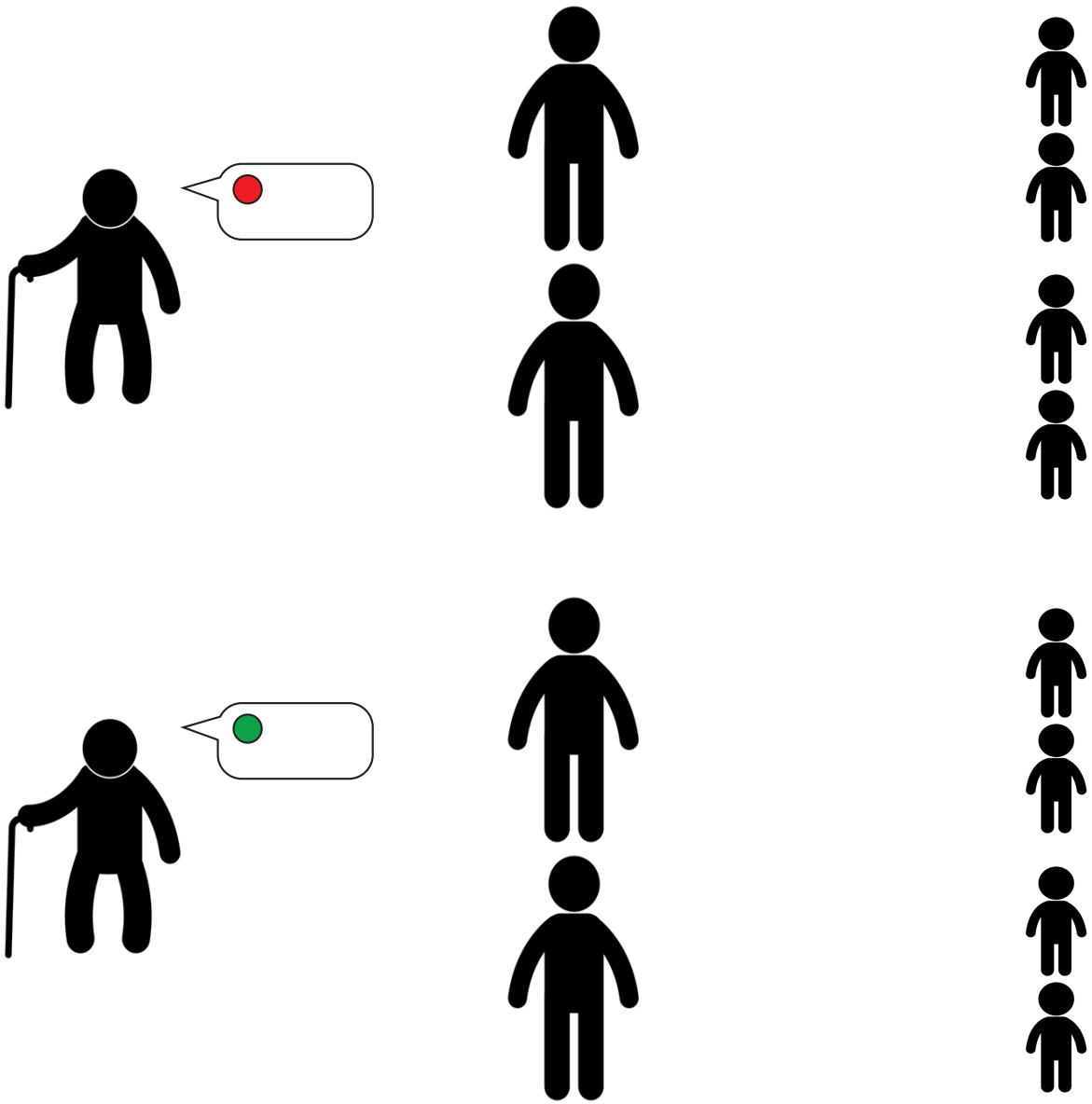
A "bad" (family) equilibrium:

- All craftsmen train their children on their own.
- If (off the equilibrium path) a master gets an apprentice, the master exploits the apprentice.
- No one gets punished.

Knowledge Transmission in Family Equilibrium



Knowledge Transmission in Family Equilibrium



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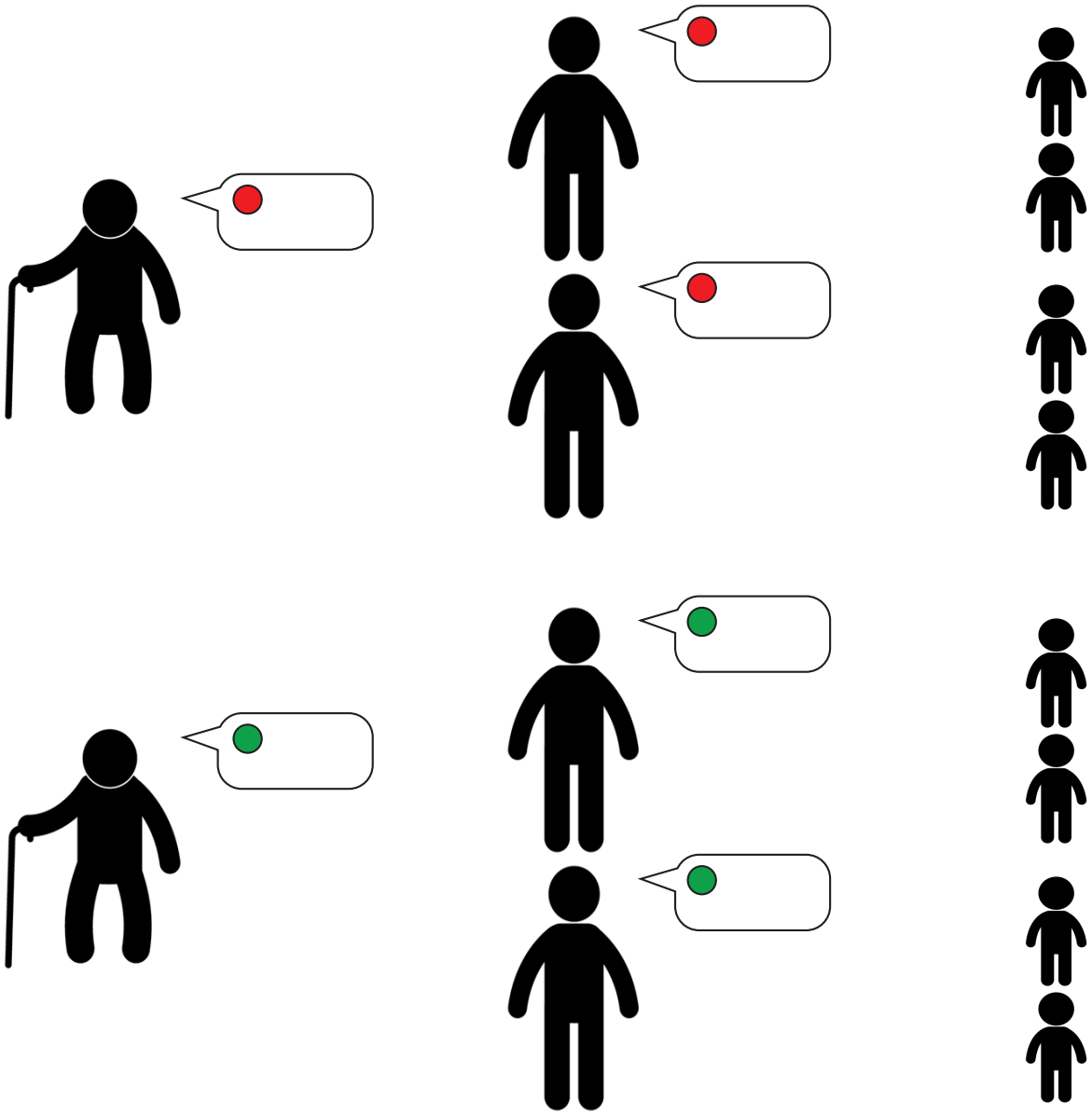

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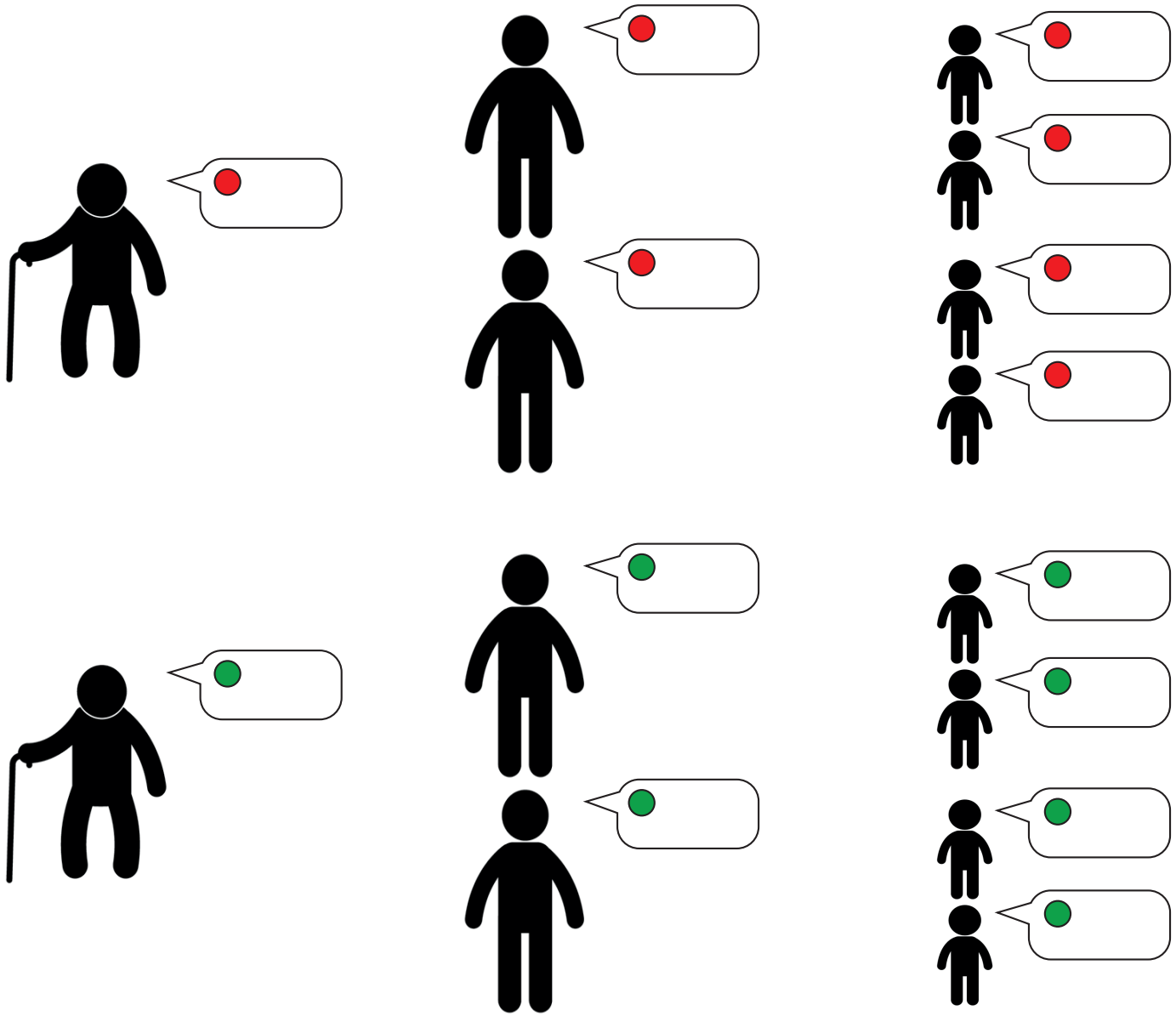

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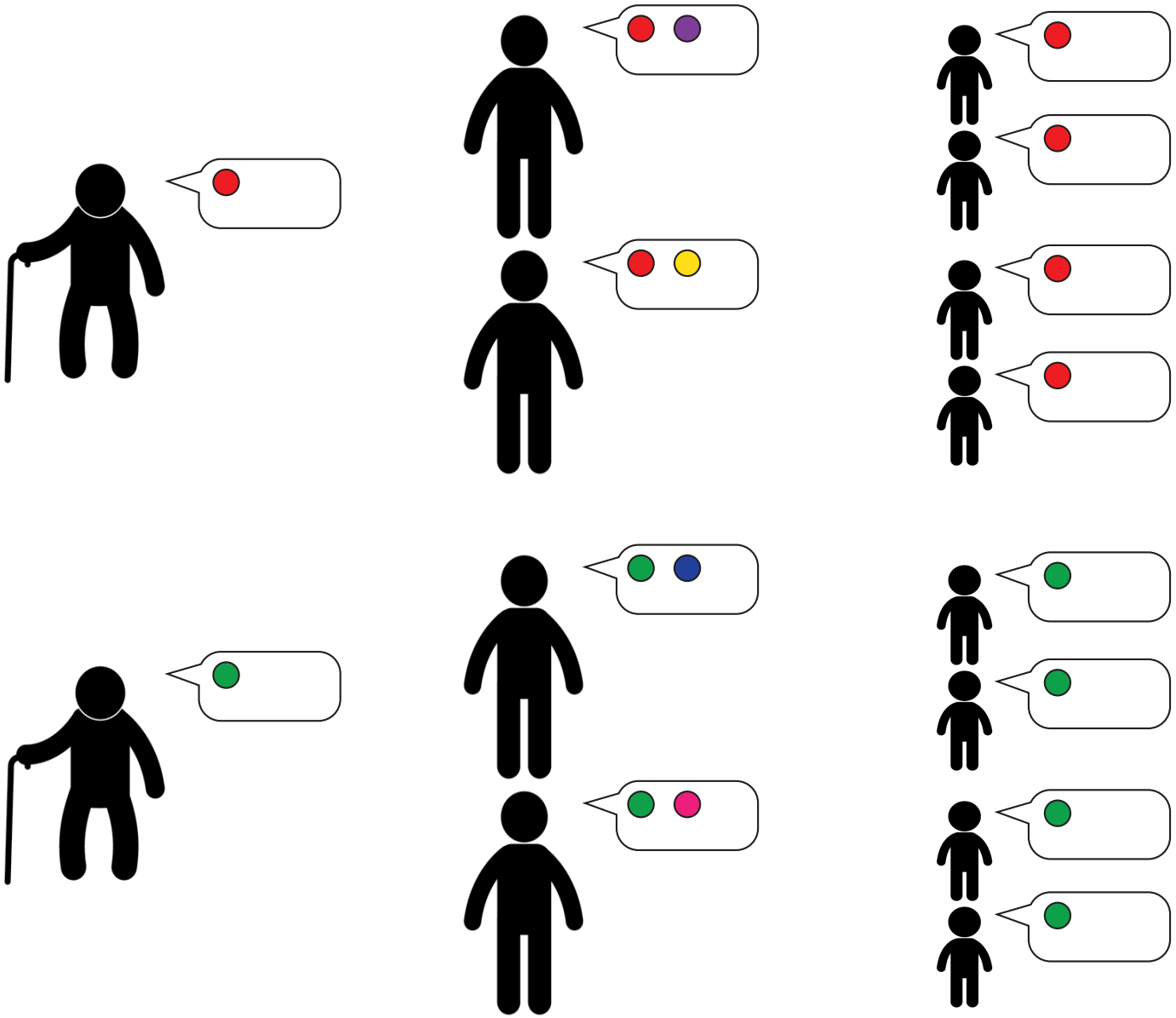

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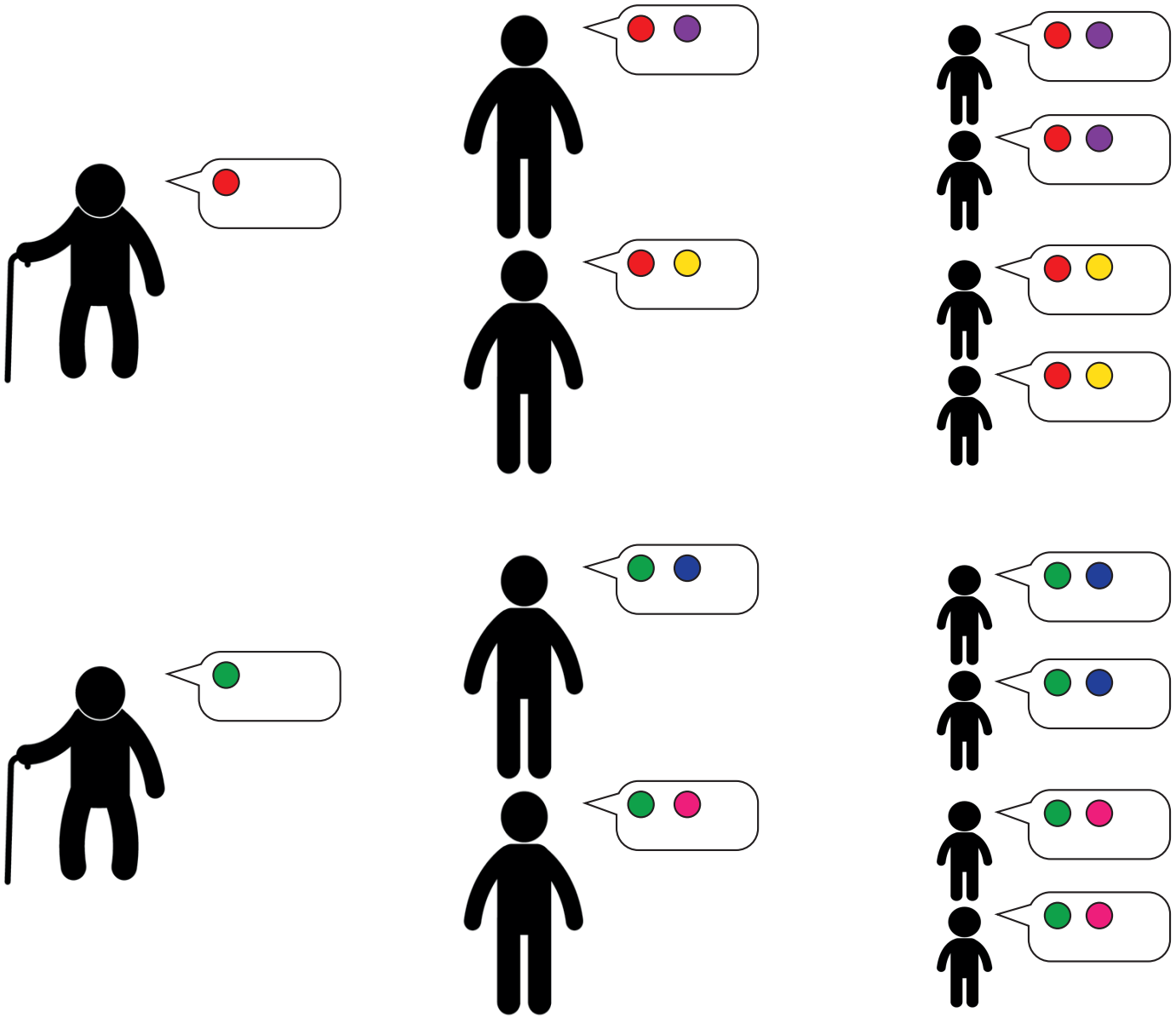


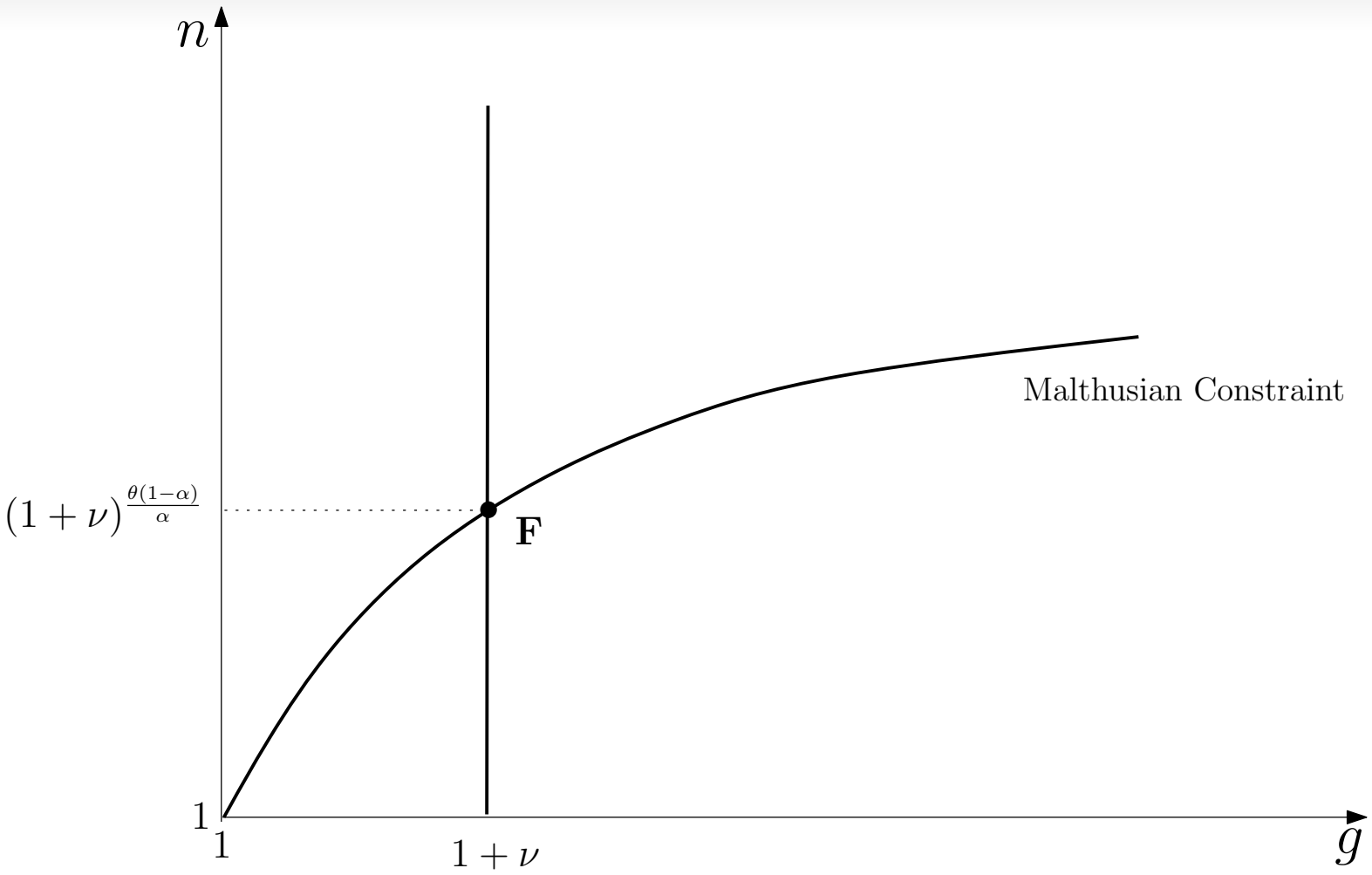
Proposition (Balanced Growth in Family Equilibrium)

There exists $\bar{\gamma}$ such that if

$$\gamma > \bar{\gamma}$$

there is a balanced growth path under the Family Equilibrium with:

- *Each child trains only with own parent: $m^{\mathbf{F}} = 1$, and $a^{\mathbf{F}} = n^{\mathbf{F}}$.*
- *Knowledge k grows at rate $g^{\mathbf{F}} = 1 + \nu$*



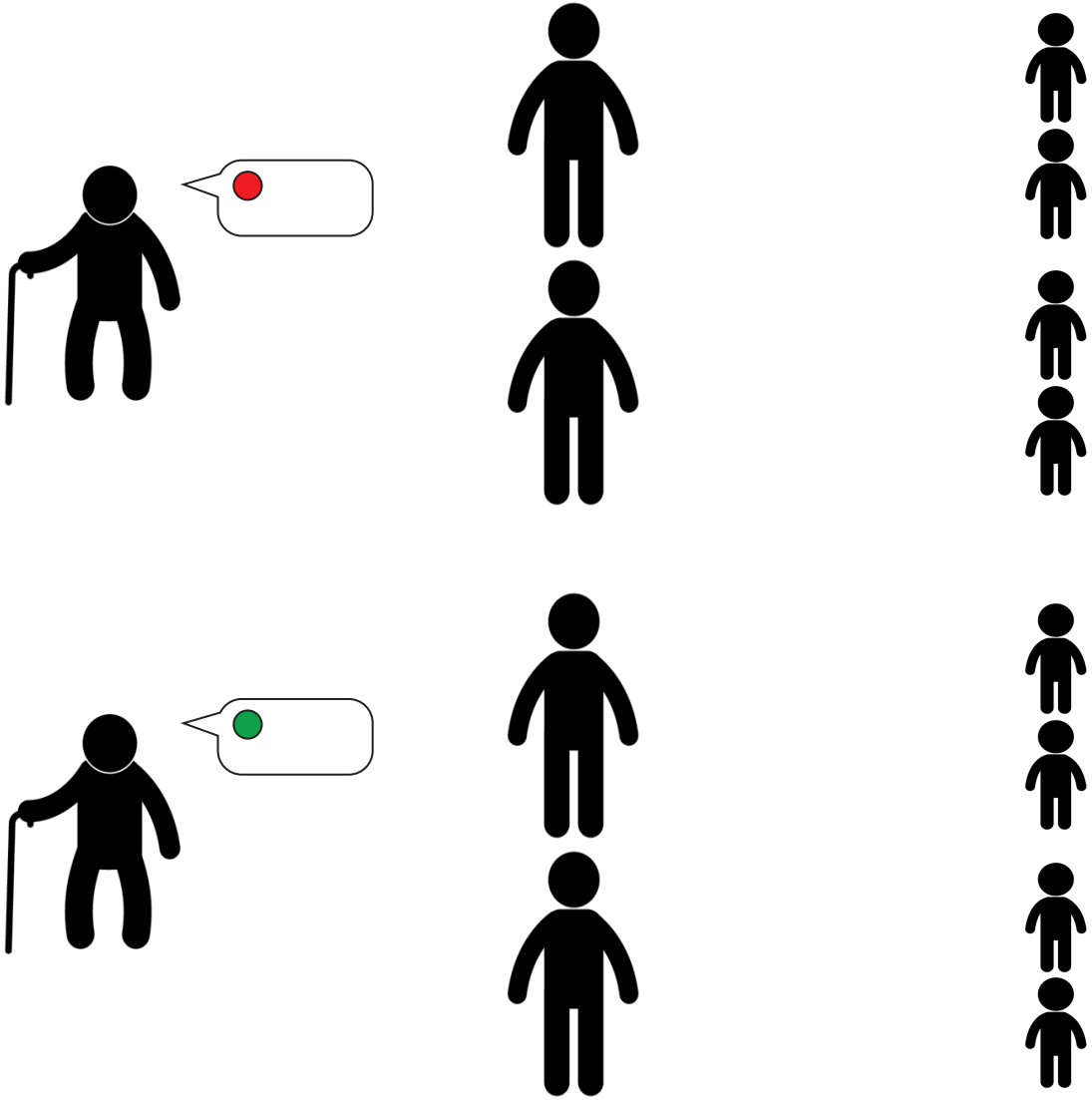
BGP in the Family Equilibrium

Punishment Equilibria

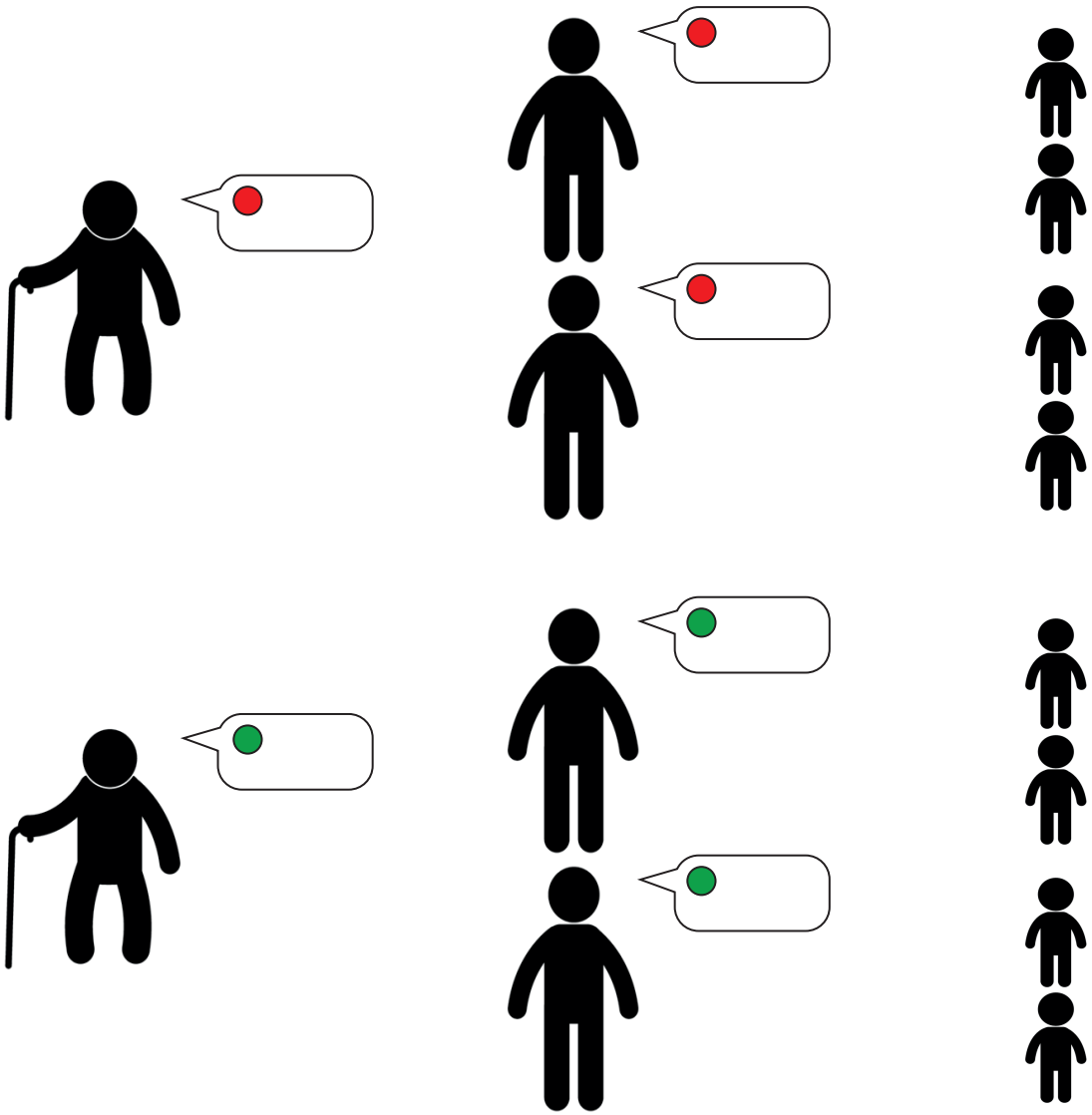
Consider punishment equilibrium. All members who share an ancestor o **generations back** communicate.

- All craftsmen send their children do be trained by all current members of the dynasty.
- Parents compensate masters for training by paying $\delta'(a) - \kappa$.
- All masters treat their apprentices fairly.
- If (off the equilibrium path) a master cheats an apprentice, all current members of the dynasty punish the master.
- If (off the equilibrium path) someone does not participate in required punishment, he gets punished also.

Knowledge Transmission in Clan Equilibrium



Knowledge Transmission in Clan Equilibrium



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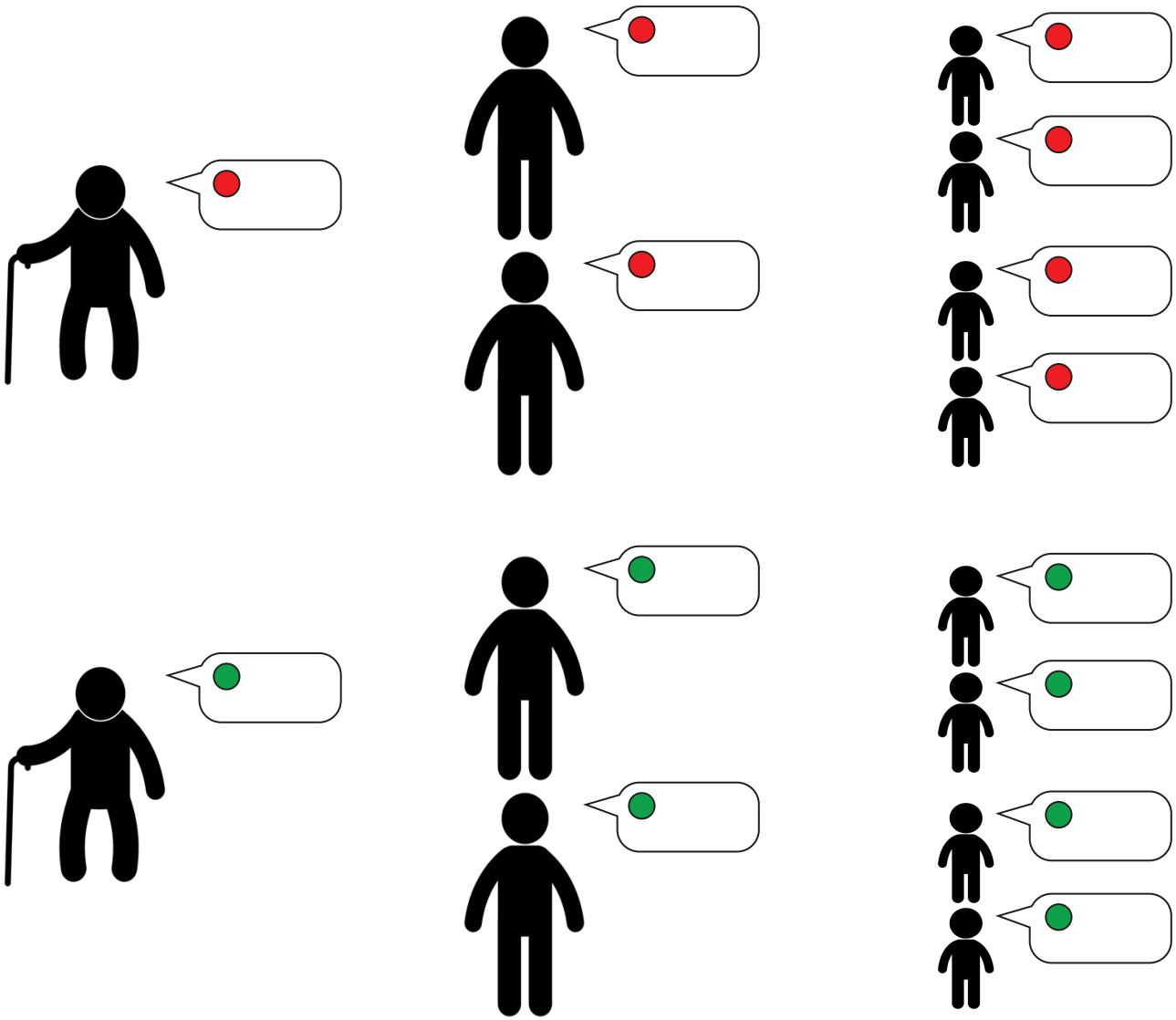

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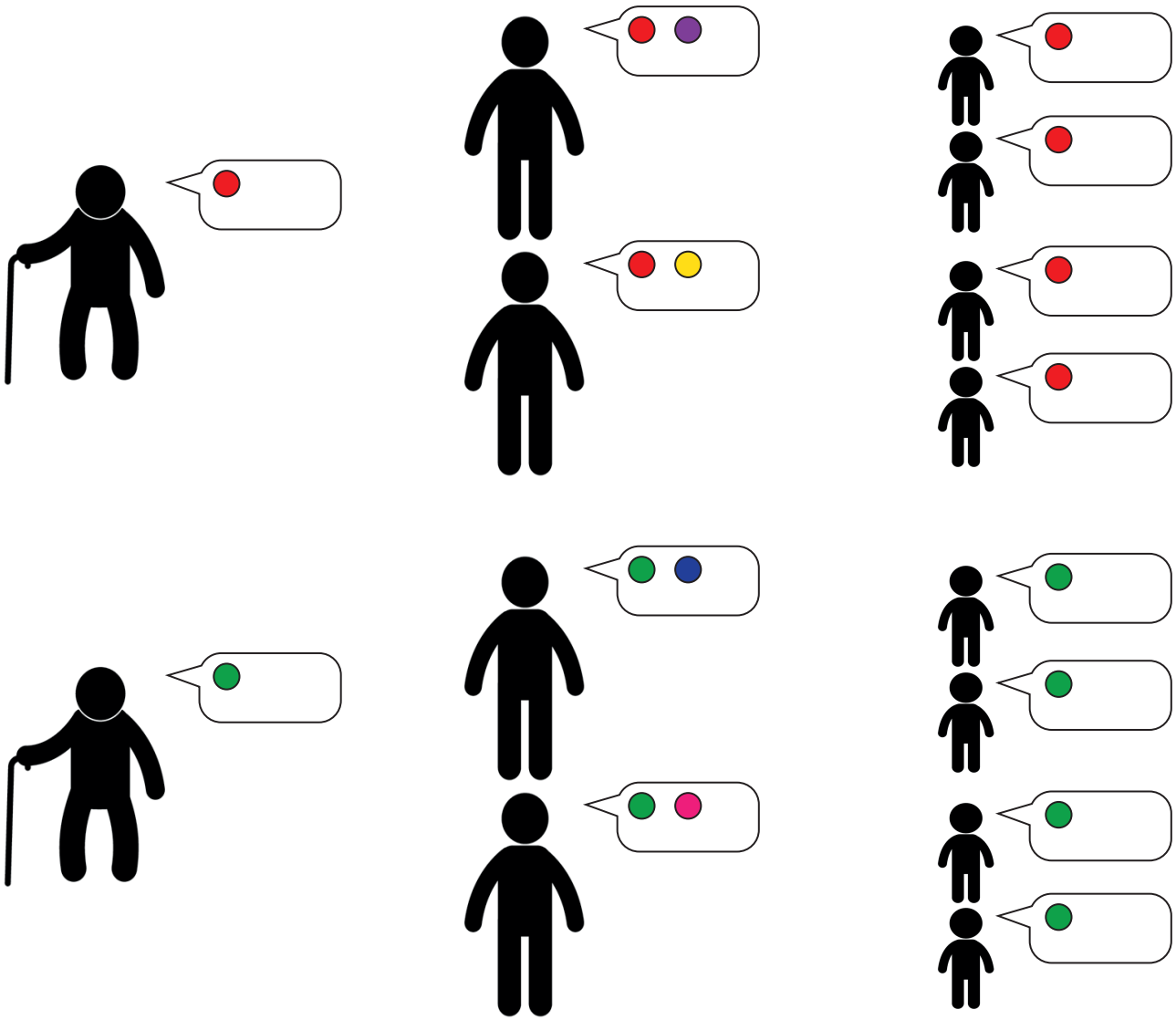

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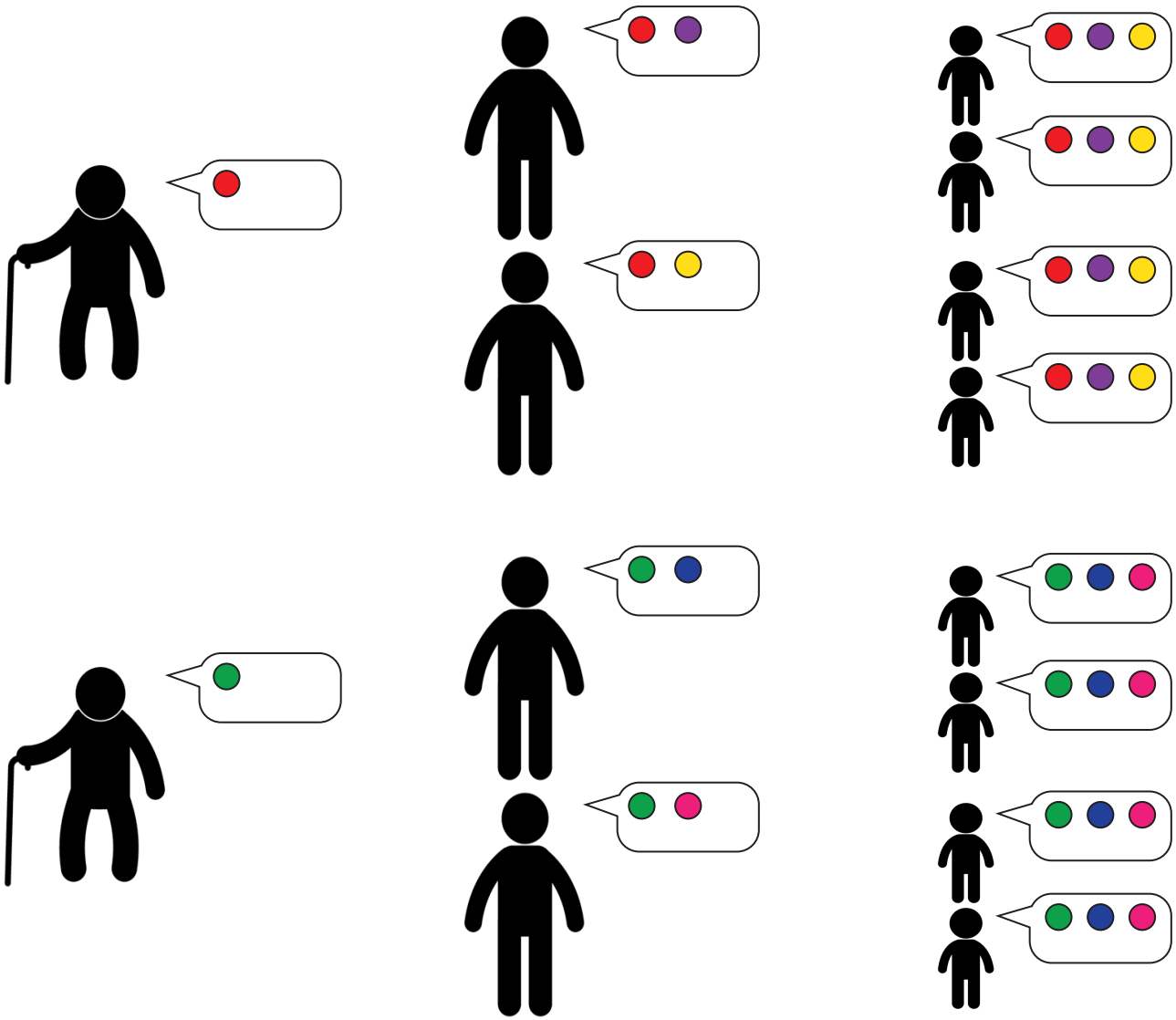


Proposition (Balanced Growth in Clan Equilibrium)

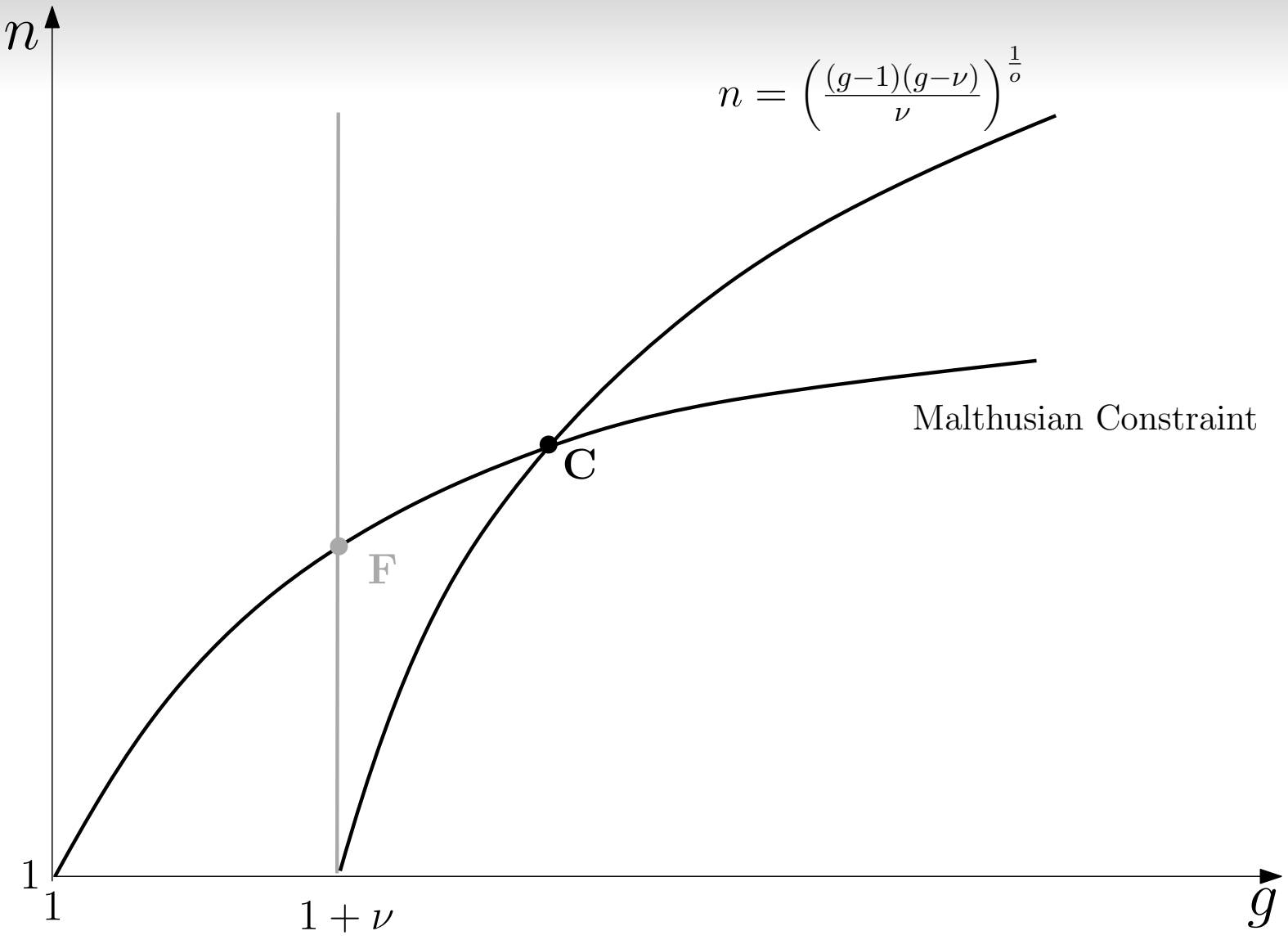
There exists $\hat{\gamma}$, $o_{\max}$ *such that if*

$$\gamma > \hat{\gamma} \quad \textit{and} \quad o < o_{\max}$$

there is a balanced growth equilibrium with:

- *The number of masters per child is equal to the number of adults in the clan:* $m^{\mathbf{c}} = (n^{\mathbf{c}})^{o}$.
- *The number of apprentices per master satisfies:* $a^{\mathbf{c}} = (n^{\mathbf{c}})^{o+1}$
- *The growth rate* $g_k^{\mathbf{c}}$ *of knowledge* k *is the solution to:*

$$g^{\mathbf{c}} = 1 + \frac{\nu\,(n^{\mathbf{c}})^{o}}{g^{\mathbf{c}} - \nu}, \tag{2}$$



BGP in the Clan Equilibrium: When fertility is higher, the clan is bigger, there are more masters and more new ideas

An Apprenticeship Market

Formal contract enforcement

Parents decide how many masters m their child will learn from at price p.

Masters decide how many apprentices to accept given price p.

Price paid by parents to masters clears the apprenticeship market.

Masters' Decision to Accept Apprentices

Given p, accept apprentices to maximize profits:

$$\max_{a} \left\{ pa + \kappa a - \delta(a) \right\}.$$

Price satisfies:

$$p = \delta'(a) - \kappa.$$

Parents' Decision to Apprentice Children

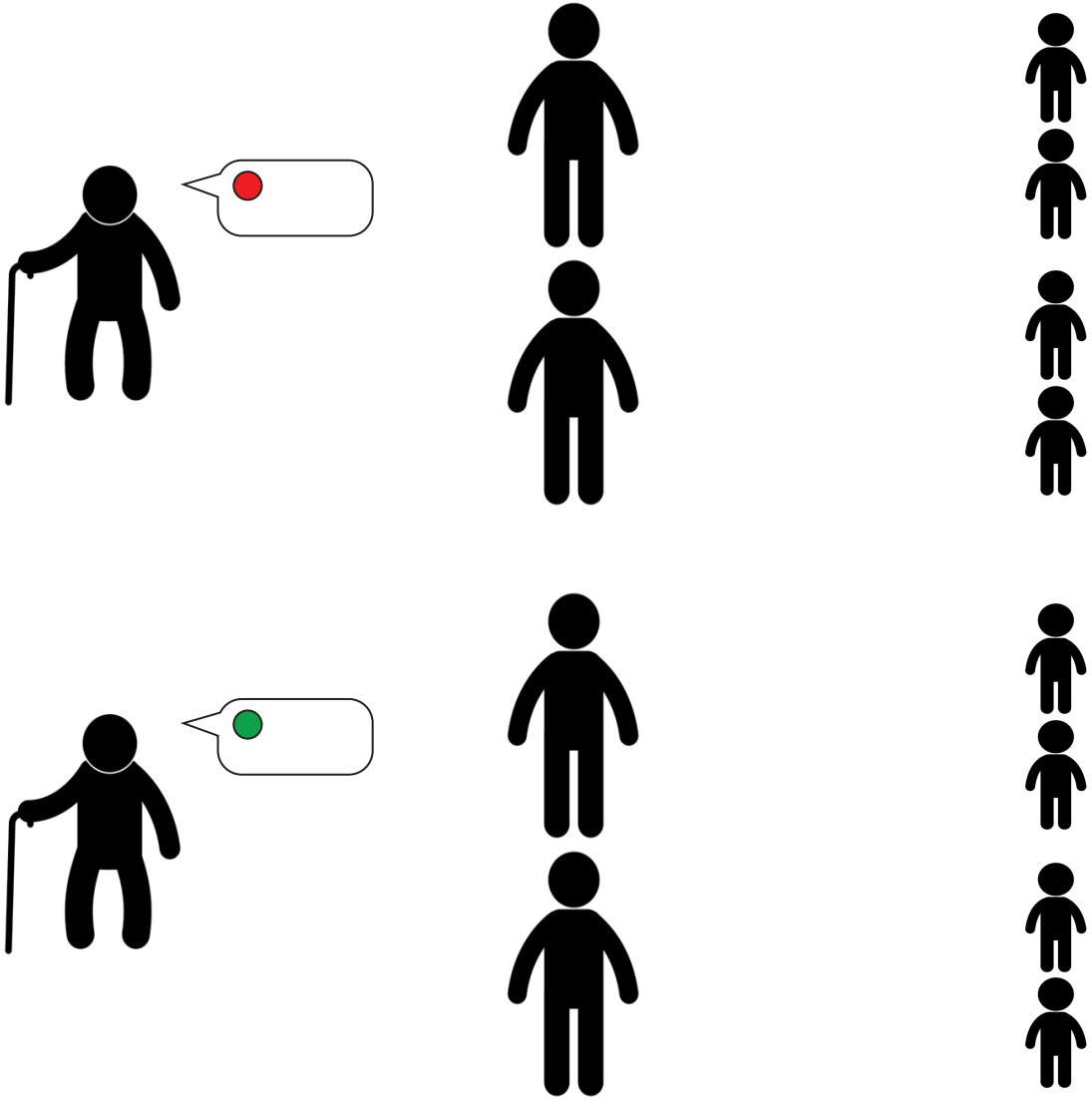
Given p, choose number of masters to maximize utility:

$$\max_{m} \mathrm{E}\left\{-p\ m\ n + \gamma\ nl'\right\},$$

First-order condition:

$$\underbrace{p}_{\text{marginal cost}} = \gamma \underbrace{\frac{\partial \mathrm{E}[q']}{\partial m}\ \beta \frac{Y'}{L'}}_{\text{marginal benefit}} .$$

Knowledge Transmission in Market Equilibrium



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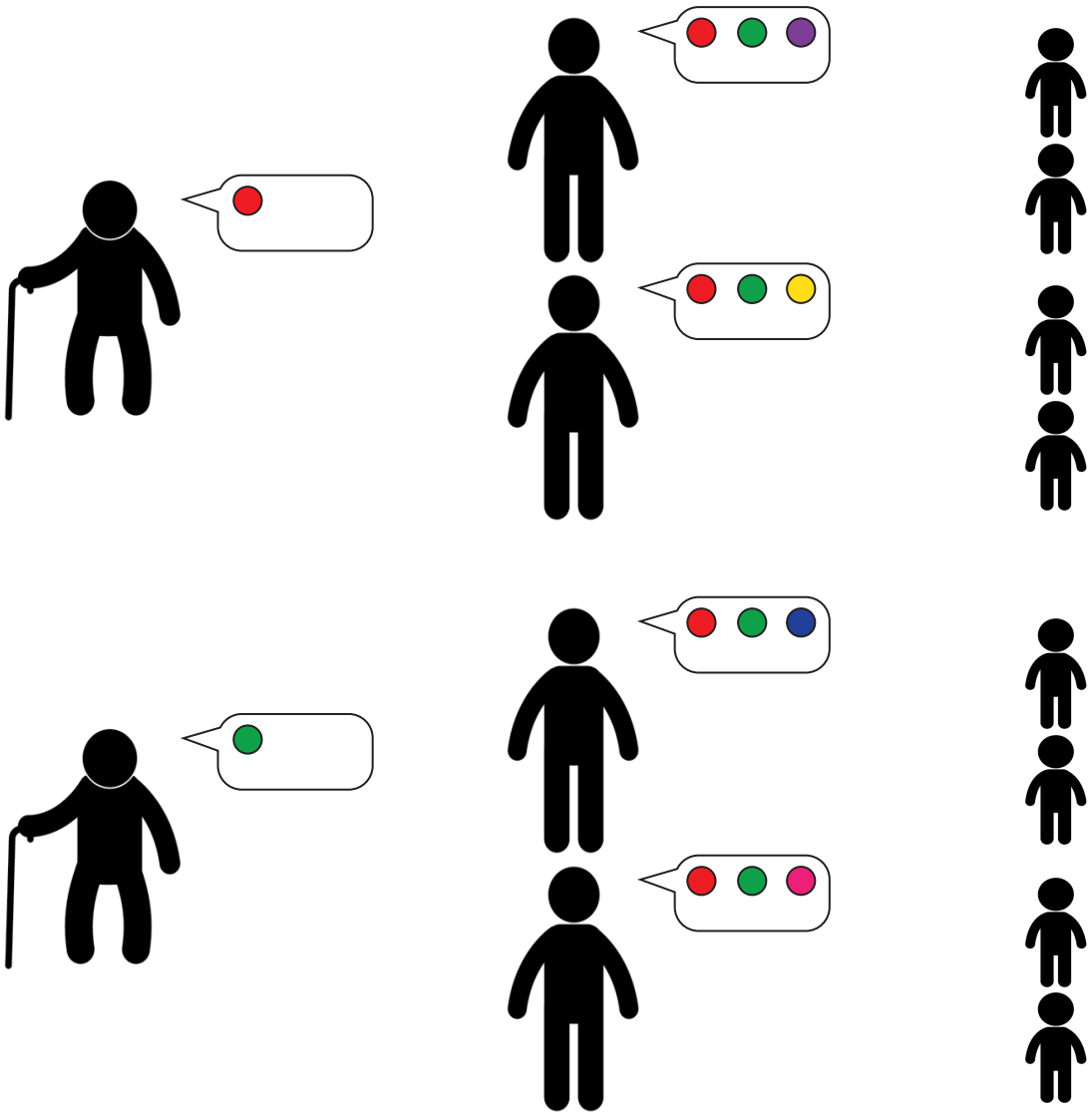

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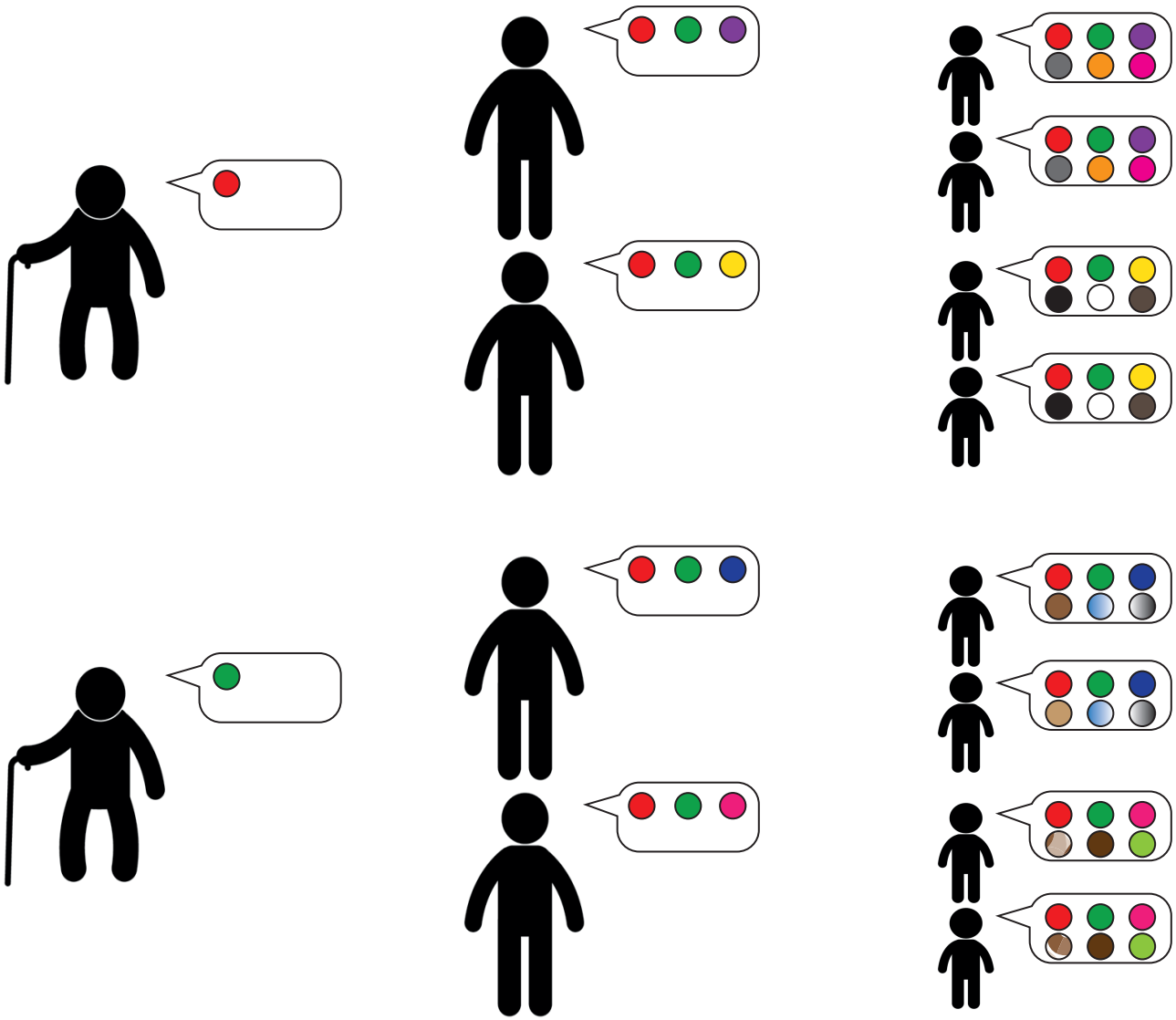


Proposition (**BGP in Market Equilibrium**)

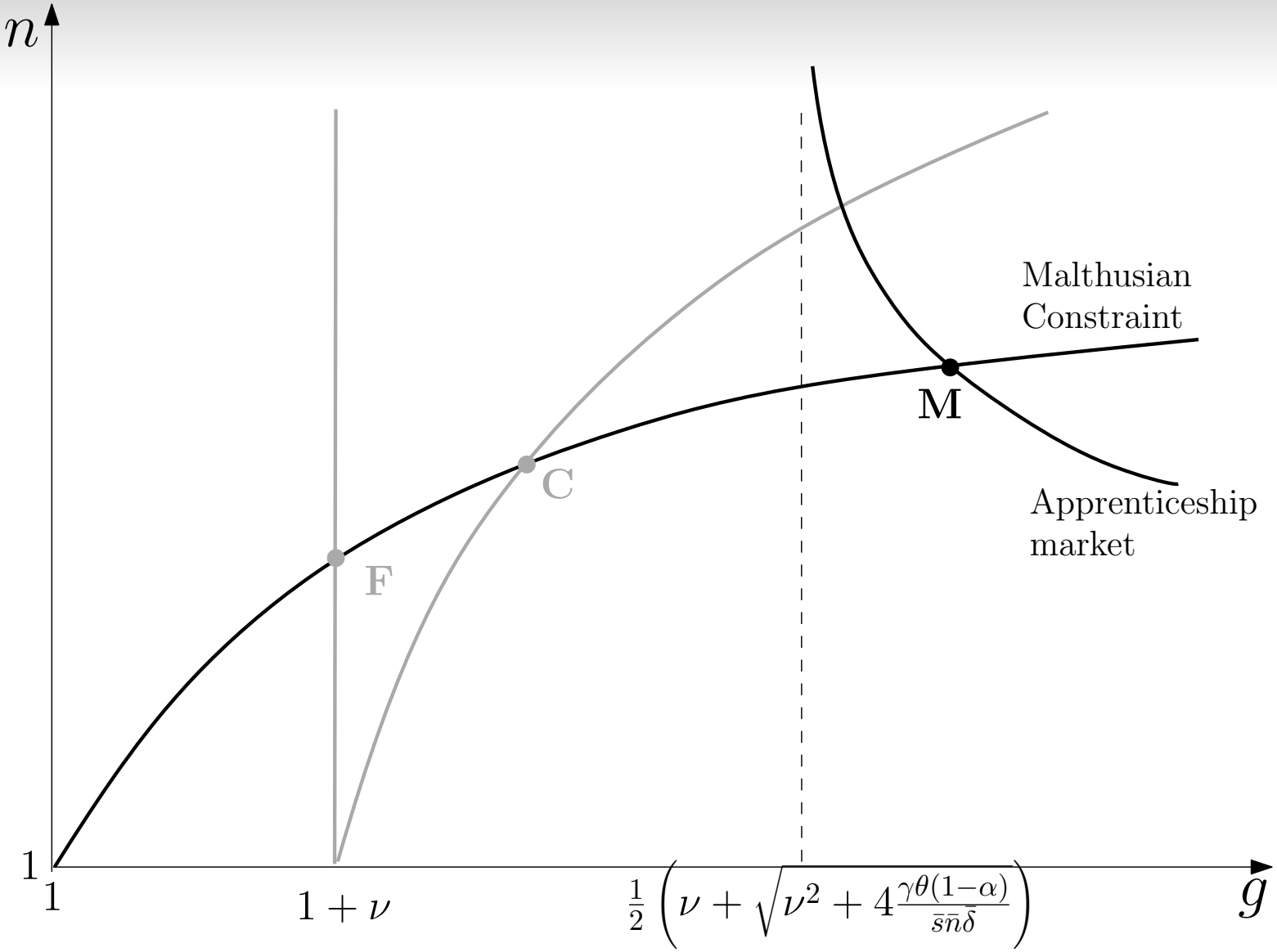
The unique balanced growth path with following properties:

- *The number of apprentices per master* a^{M} *solves:*

$$\delta'(a^{\mathsf{M}}) - \kappa = \gamma\theta(1-\alpha)\frac{1}{a^{\mathsf{M}}/n^{\mathsf{M}} + \nu}y^{\mathsf{M}} \tag{3}$$

  The number of masters per child m^{M}*:* $m^{\mathsf{M}} = a^{\mathsf{M}}/n^{\mathsf{M}}$*.*
- *The growth rate* g^{M} *of knowledge* k *is* $g^{\mathsf{M}} = m^{\mathsf{M}} + \nu$

The Market Equilibrium yields higher growth in productivity and population and higher income per capita than the Clan Equilibrium.



Apprenticeship market: High fertility $\rightarrow$ tight market for apprenticeships $\rightarrow$ high equilibrium price $\rightarrow$ parents demand few masters.

The Guild

Positive channel: Need institution that enforces apprenticeship contract. Guilds provided such an institution when government-provided enforcement was less effective.

Negative channel: By restricting access to and raising price of apprenticeship, guilds lower rate of knowledge growth.

Guild Equilibrium

$S_j N'$ kids look for apprenticeship in trade j.

Coalition of masters in a given trade lowers the maximum number of apprentices per master a to increase the price.

$$\begin{aligned} \max_{a_j} \quad & \left\{ p_j a_j - \delta(a_j) + \kappa a_j \right\} \\ \text{subject to} \quad & S_j N' m_j = N a_j, \\ & p_j = \gamma \frac{\partial EI'_{ij}}{\partial m_j}, \\ & EI'_{ij} - p_j m_j = (1-\alpha) \frac{Y'}{N'} - pm. \end{aligned}$$

Constraints: Parents demand less apprenticeship and/or send kids to other trades.

Proposition (Balanced Growth in Guild Equilibrium)

The unique balanced growth path in the Guild Equilibrium has the following properties:

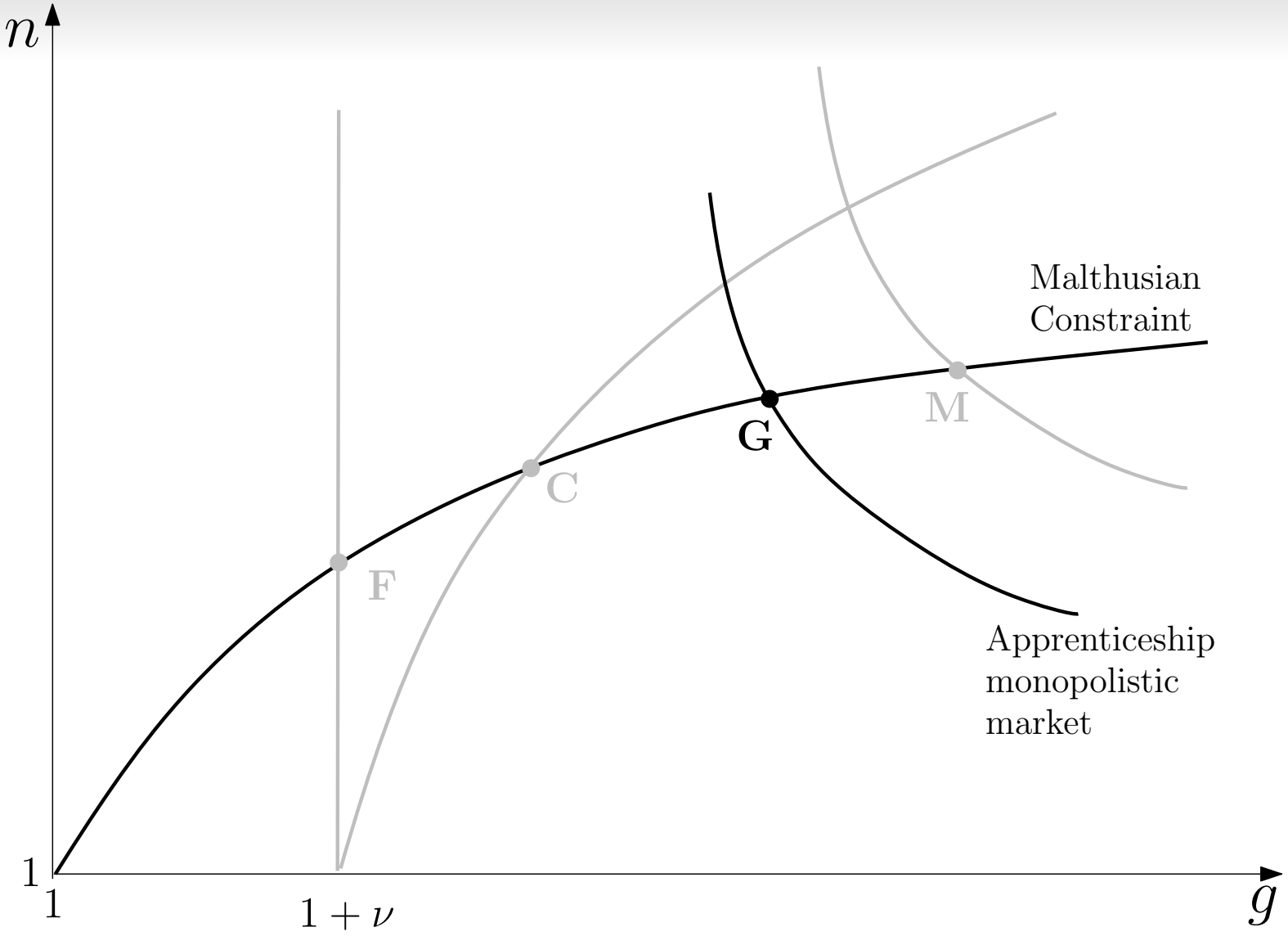
The number of apprentices per master a^G solves:

$$\delta'(a) - \kappa = \gamma\theta(1-\alpha)\frac{1}{m+\nu}\frac{Y'}{N'}\Omega(m)$$

The number of masters per child m^G is the solution to $m^G = a^G/n^G$.

The growth rate g^G of knowledge k is $g^G = m^G + \nu$

For $\lambda > 1$, $\Omega(m) < 1$, the Guild Equilibrium yields lower growth in productivity and population and lower income per capita than the Market Equilibrium.



the Guild Equilibrium

Numerical example

One period (generation) is interpreted as 25 years.

$\alpha = 0.8$, $\theta = 0.25$, $\gamma = 0.1$, $\bar{n} = 2$, $s = 7.5$, $o = 3$, $\kappa = 0.02$, $\lambda = 4$.

set ν to reproduce growth rate of population of 0.86 percent per generation in the family equilibrium (10000 BCE – 1000 CE)

set cost of training s.t. number of masters per apprentice m is identical in the clan and guild equilibria

	$g-1$	$n-1$	m	Y/N
Family Equilibrium (**F**)	14.7%	0.86%	1	6.724
Clan Equilibrium (**C**)	14.9%	0.87%	1.018	6.725
Guild Equilibrium (**G**)	16.4%	0.96%	1.018	6.730
Market Equilibrium (**M**)	17.7%	1.02%	1.030	6.735

Technological leadership

By 1000 CE, technological leadership of China.
ex: the "Four Great Inventions", paper, woodblock printing, magnetic compass, gunpowder

Around 1100 CE, rise of self-governed communes in Europe (Pisa, Le Mans, Utrecht, Cologne) and expansion of craft guilds

Europe catched-up:

- 1282: first hydrolic papermill in Aragon
- c. 1300: dry compass invented
- 1429: corned gunpowder invented
- 1439: Gutenberg's printing press

Initial conditions

Europe: Church discouraged practices sustaining kinship groups.
By the ninth century the nuclear family predominated.

Example: Distinction between paternal and maternal relatives disappeared from Romance language by 600 CE
Spiritual kinships analogous to blood kinships (Mitterauer, 2010)

Rest of the world: mostly extended family

ex: China: Confucianism considers moral obligations among kin as the basis for social order (Greif and Tabellini, 2010).
Kinship system emphasising patrilineality (father's lineage).

Example: in 624 CE, Tang penal code defines penalties function of grades of relational positions
hitting a paternal grandparent $\rightarrow$ decapitation
hitting a neutral person $\rightarrow$ 40 blows with the light stick

Rise of Europe Primacy

Consider possibility of adopting market / guild at fixed cost $\mu(N)$ (e.g., cost of moving to city with enforcement institutions).

Proposition (**Adopting G easier starting from F**)

Consider two economies with the same initial knowledge and population, one in the family equilibrium, and one in the clan equilibrium.

$\exists$ *thresholds* $\underline{N}$ *and* $\overline{N}$*, with* $\underline{N} < \overline{N}$*, such that:*

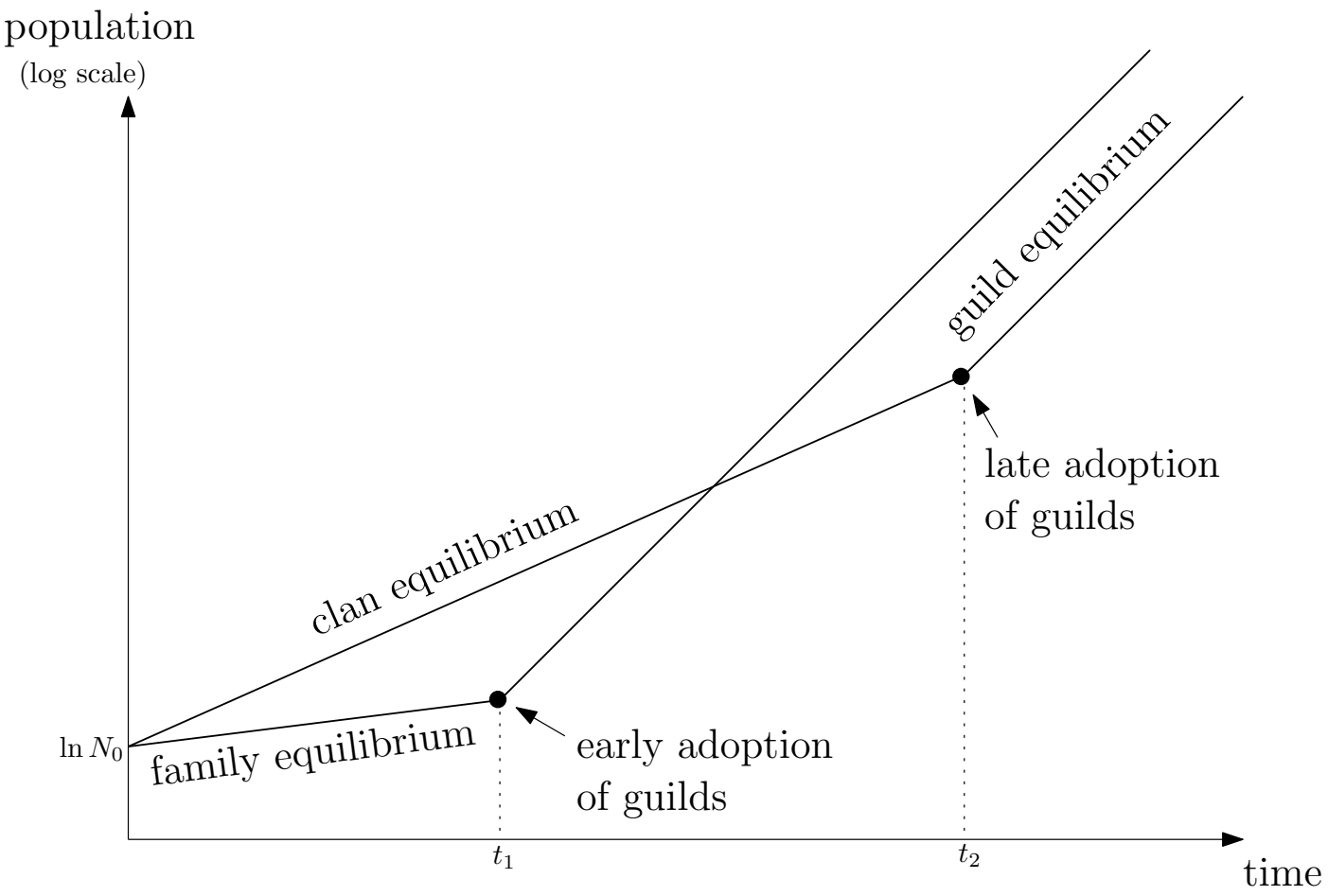
- ▷ *if* $N_0 < \underline{N}$*, none of the economies adopt the guild institution.*
- ▷ *if* $\underline{N} \leq N_0 \leq \overline{N}$*, only the economy in the family equilibrium adopts the guild institution.*
- ▷ *if* $\overline{N} < N_0$*, both economies adopt the guild institution.*

Gain from adopting market larger when initial equilibrium worse.

Thus, Europe (family equilibrium) more likely to adopt the market compared to Rest of the world (clan equilibrium).

Intra-clan enforcement reduced the need for formal enforcement institutions.

Possible dynamics of two Economies Starting from the Same N_0



Numerical example

Two economies, identical but initial equilibrium.

Same technology level in 450CE (Morris (2010)).

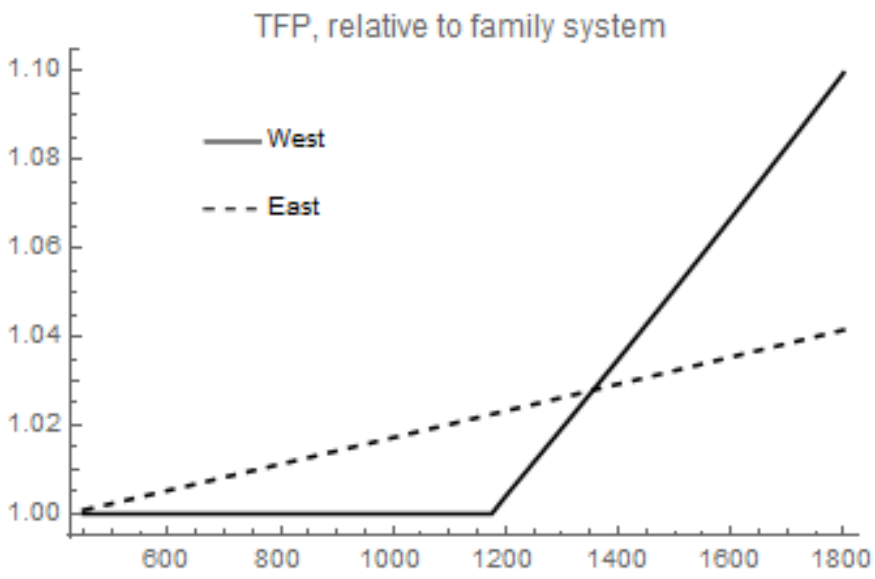
By 1200CE, clan economy has cumulated an advantage in TFP level of 2.3% (15% in Morris).

Population density is larger in the clan economy (bigger cities in China than in Europe).

Suppose the West fully adopts guilds in 1200CE (upper bound).

Gap in TFP will be closed by 1400CE (1700CE in data)

By 1800CE, West has advantage in TFP by 5.6%. Population density catched-up (London as populated as Beijing).



Additional determinants of $\mu(N)$

If cost of adoption of guilds depends on population density, the "effective" population density would have been much higher in Europe, because craftsmen were concentrated in small urban areas.

$\neq$ China where 97 percent of population lived outside walled cities
$+$ Chinese manufacturing was much less concentrated in cities (Rosenthal)

In the model above, such a difference would be represented as a lower level of the cost function $\mu(N)$ for a given overall population.

Main driver of technological change in history?

Two extreme views

(a) innovation is driven entirely by UTHC – scientists and mathematicians who push the envelope of propositional knowledge which gets applied.

(b) driven entirely by artisanal knowledge, which gets improved over time if the incentives are right, through learning by doing and the occurrence of improvements through trial-and-error and serendipity. Formal and codified knowledge play no role.

here we focused on (b), without denying the complementarities between the dissemination and the creation of knowledge ...

Final example

British watch industry in the eighteenth century
– originally regulated by a guild (the Worshipful Company of Clockmakers)
– by 1700 more or less free of guild restrictions
– Training exclusively through master-apprentice relations.

– Major technological shock by the invention of the spiral-spring balance in watches (ca. 1675).
– No similar macro-invention occurred in the subsequent century.

The real price of watches fell by an average of 1.3 percent a year between 1685 and 1810 (Kelly and Ó Gráda)

Summary

Not all forms of apprenticeship were created equal, and the systems differed over time and across space.

Differences in how to deal with the moral-hazard problem underlying the apprentice-master relationship.

Systems adopted in Europe allowed knowledge to cross family lines and spread faster

Small artisans were key for European success. In Europe, artisans got better over time because of favorable institutions.