WHAT IS IT?

Fertility Tradeoffs is a NetLogo model that illustrates the emergencent tradeoffs between the quality and quantity of offspring. Often, we associate high fitness with maximizing the number of offspring. However, under certain circumstances, it pays instead to optimize the number of offspring, having fewer offspring than is possible. When the number of offspring is reduced, more energy can be invested in each offspring, which can be beneficial for their own fitness.

HOW IT WORKS

When the model is initialized, a population of humans are created and placed in cells. Each square cell of the model is inhabited with at most one human. Some cells are uninhabited and appear black.

At each timestep, humans (i) earn money based on their education level, (ii) use the money to buy adjacent cells for their spouse and child, and (iii) invest in the education of that child. The INCOME-PER-EDUCATION-LEVEL parameter sets the amount of money humans receive per education level per timestep. The COST-PER-EDUCATION-LEVEL sets the amount of money parents have to pay for their child to earn each education level. Human parents and their child form a “household” of adjacent cells, which are visually represented by color. Many humans may be interested in buying a particular cell and so each cell is auctioned off to the highest bidding human.

Humans have one evolving (heritable) trait: preferred education level. Parents must use their money to pay for their child’s education until their child reaches their preferred education level. The higher the preferred education level, the longer and more expensive their educational career will be. Once a child reaches their preferred education level, they become adults and leave their parent’s household to establish their own household: buying cells, finding spouses, and making their own children. Human parents only direct their efforts towards one child at a time but, depending on how demanding each child is, they can potentially have several children in a lifetime.

At each timestep, humans have the possibity of dying. The OFFSPRING-MORALITY-RATE parameter dictates, on average, what percentage of children will die at each time step; the ADULT-MORTALITY-RATE does the equivalent for adults.

HOW TO USE IT

Parameter Settings

The ADULT-MORTALITY-RATE slider determines the mortality rate of adult humans (adults have left their natal household and have reached their preferred education level). Setting this value too high will result in a population-wide extinction - the inverse of this value is roughly equal to the average lifespan in ticks. Here we are modeling humans and so this parameter is initally set to 0.015, or 67 ticks (years).

The OFFSPRING-MORALITY-RATE slider determines the mortality rate of humans who are classified as children (children still live in their parent's household and haven't completed their preferred education level). This value can be more variable than the ADULT-MORTALITY-RATE, but the specific setting has potentially deep implications for the optimal reproductive strategy!

The INCOME-PER-EDUCATION-LEVEL slider determines the value of each unit of education level. The income a human receives per timestep is calculated as follows:

INCOME = CURRENT-EDUCATION x INCOME-PER-EDUCATION-LEVEL

The COST-PER-EDUCATION-LEVEL slider determines the cost per unit of education level. Human parents must pay this amount for each unit of education their child requires.

Buttons

Press SETUP after all of the settings have been chosen. This will initialize the program to create a population of humans.

Press GO to make the simulation run continuously. Humans will occupy their time earning money, buying cells, finding spouses, and reproducing. To stop the simulation, press the GO button again.

Output

While it is running, the simulation will show population-level results in four graphs:

The ECONOMY OVER TIME graph shows trends in the population's economy over time. "Real Estate Cost" tracks the median cost per cell. "Education Cost" tracks the median cost of education per human. "Household Income" tracks the median amount of money per household. Positive trends over time indicate a booming economy while negative trends over time indicate a collasping economy.

The TRADEOFFS OVER TIME graph shows trends in the population's reproductive tradeoffs over time. "Number of Children" tracks the median number of children per human. "Education Level" tracks the median preferred education level per human.

The INSTANTANEOUS EDUCATION VS. FERTILITY graph displays the current reproductive and educational status of each adult human. Each human is represented by a dot that is placed on the graph to indicate their current education level and current number of children. This graph refreshes at each timestep.

THINGS TO NOTICE

The purpose of this model is to demonstrate that humans (and other organisms) experience reproductive tradeoffs: quality of offspring vs. quantity of offspring. The preferred reproductive strategy is context dependent and this model explores the effect of adult and childhood mortality rates. Pay attention to how the settings affect the economy, number of children per human, and preferred education level:

1. When running simulations, notice that there is an inverse relationship between a strategy for more children a strategy for investment in education. Typically two types of strategies emerge: (1) many-children/low-education, and (2) few-children/high-education.

2. Keeping everything else constant, how does the OFFSPRING-MORALITY-RATE affect the preferred reproductive strategy of the population?

3. When you find settings that result in a many-children/low-education reproductive strategy, keep these settings constant and vary COST-PER-EDUCATION-LEVEL. Is it possible to reduce the investment cost such that a few-children/high-education reproductive strategy emerges? Or vice versa?

4. How do the observed results match known human socities?

HOW TO CITE

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This model was created at the University of Minnesota as part of a series of applets to illustrate principles in biological evolution.

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