The cause of growing foreign-trained nurse concentration and its impact

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Abstract

Working with a group from Singapore's Ministry of Health we were presented with the dilemma of an ever increasing fraction of foreign nurses despite efforts to increase domestic nurse training capacity. To understand why this might occur we developed a model embodying the hypotheses put forward by the group. The resulting model shows how drifting goals and a focus on rates instead of levels can lead to the observed behavior. We find that as foreign nurse hiring increases, the pressure to educate domestic nurses decreases. Thus, as the burden to reduce a nurse shortage gradually shifts to an external supply of trained nurses, longer term domestic training capacity dissipates. Establishing a fixed desired fraction of foreign nurses keeps the focus on maintaining domestic training capacity. In addition, with an enrollment that is based on the stock values of students and domestic nurses, average residence time of domestic nurses, and delays in training, the system demonstrates greater stability.

Keywords: nursing capacity, foreign nurses, local nurses, goal erosion, drifting goal, goal setting, nurse shortages

Introduction

The Duke-NUS Graduate Medical School Program in Health Services and Systems Research established a Health Systems Design Laboratory (HSDL) to advance the use of systems-based research methodologies, in particular, System Dynamics. HSDL collaborated with the Singapore Ministry of Health (MOH) to help them with nursing capacity planning over a 20-year horizon. At the strategic level, population trends and overall nursing capacity affect supply and demand for nurses . The supply and demand for nurses also influence operational issues, such as experience level, quality of care, turnover rate, and workload.

This paper is a post-project work inspired by one verbal reference repeatedly mentioned by stakeholders from the MOH: there are more and more foreign-trained nurses in the country every year. Although we only have this verbal reference, we gathered the suggested hypotheses for why this might be happening and built a system dynamics model commensurate with these to explore the issue.

In the next section, we explain the structure of our model. Following that, we analyze the implication of the nursing capacity planning process on the number of foreign-trained nurses. Finally we conduct scenario testing to assess the reasons for changes in the number of foreign-trained nurses and identify leverage points where interventions can be introduced to control these changes.

Model Structure

The model consists of 5 stocks and the feedback mechanisms that control their behavior. These stocks are: students in training, domestic nurses, perceived relative gap, target fraction foreign nurses and foreign-trained nurses.
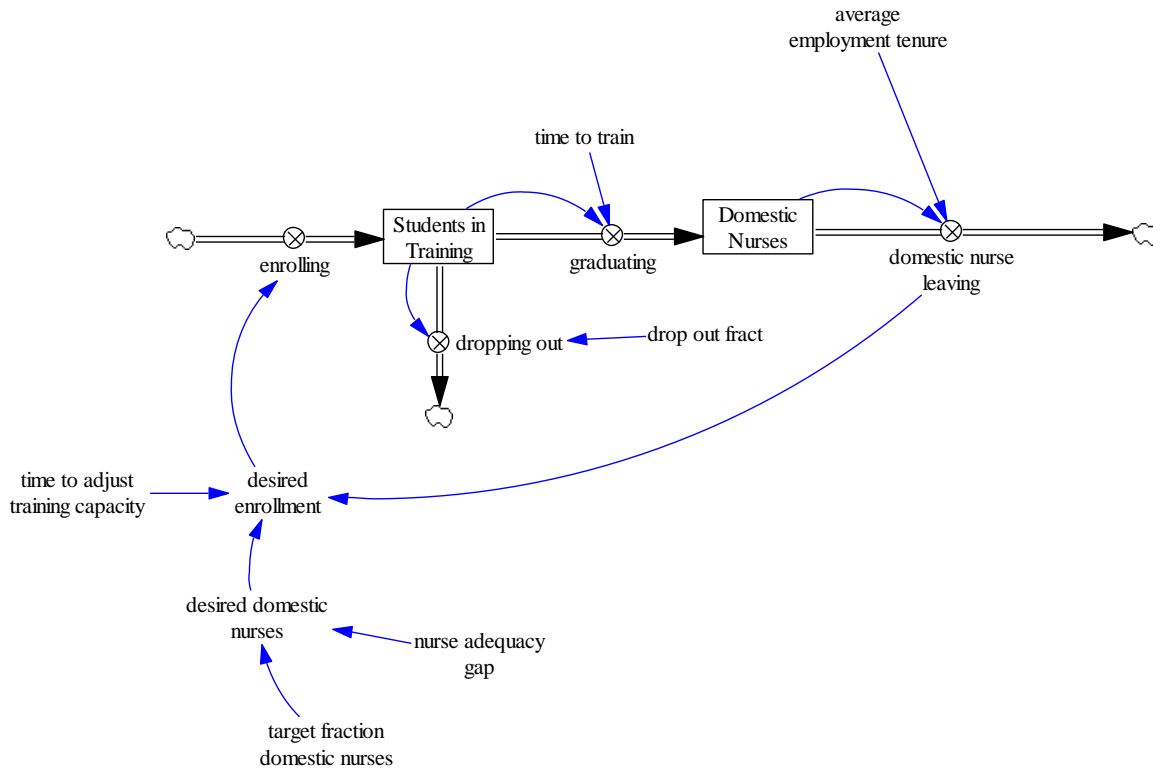

Figure 1 Transition process of nursing students to domestic nurses

Figure 1 illustrates the transition of students in nursing program to working nurses. The number of students enrolled in the nursing program is determined by nurse adequacy gap and the domestic nurses who are leaving the system. Target fraction domestic nurses is the desired fraction of domestic nurses that policy makers intend to maintain in the system. By including the expected replacement rate (domestic nurse leaving) in desired enrollment, the gap will be zero once the system settles into steady state . Adjustments to enrollment take place over the time to adjust training capacity. That is, enrolling closes a fraction of the gap in nurses needed at a rate of 1/time to adjust training capacity. These students, if they do not drop out, graduate after three years of training. It is assumed that all local-trained graduates are hired as domestic nurses.

The career length of domestic nurses is termed as average employment tenure. After that time, they leave the profession for various reasons, including going into a different field, starting a family, caring for family members or retiring. On average, domestic nurses stay in the profession for a longer period than do foreign nurses. This, in addition to the hiring process for foreign nurses discussed below, is an important distinguishing characteristic between foreign and domestic nurses.
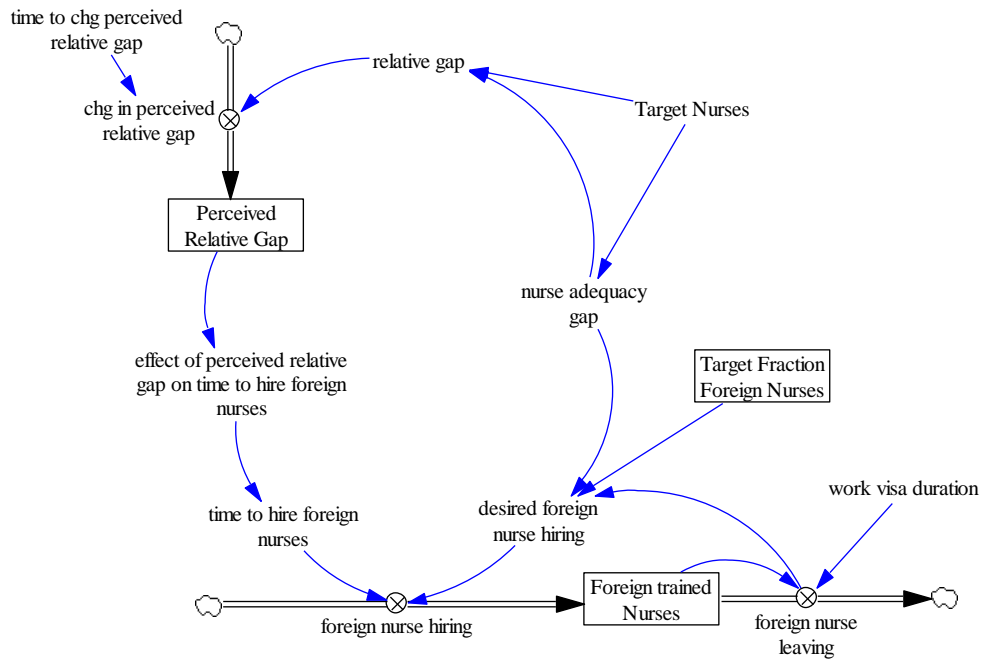
Figure 2 Stock and Flow of Foreign-trained Nurses and the impact of Perceived Gap on time to hire foreign nurse

Figure 2 is a stock and flow structure that depicts the hiring and leaving of foreign nurses. The hiring of foreign nurses is determined by the deficit of nurses and the time it takes to hire foreign nurses. The time taken to hire foreign nurses changes according to the perceived size of the relative gap; relative gap is the ratio of the shortfall in nurses to the targeted number of nurses. Perceived relative gap is the perception of the policy makers on the relative gap size. In steady state, perceived relative gap equals to relative gap. When a nurse shortage appears, perceived relative gap adjusts toward the relative gap over the time to change perceived relative gap. Perceived relative gap has an inverse relationship with time to hire foreign nurses; *a*s perceived relative gap grows, the time taken to hire foreign nurses is reduced (that is more aggressive adjustments to alleviate the nurse shortage). Foreign-trained nurses are assumed to remain employed until their work visas expire and then they exit the system. In this model, work visa duration is 3 years, much shorter than average employment tenure of domestic nurses. Hence, the turnover of foreign-trained nurses is higher than that of domestic nurses.
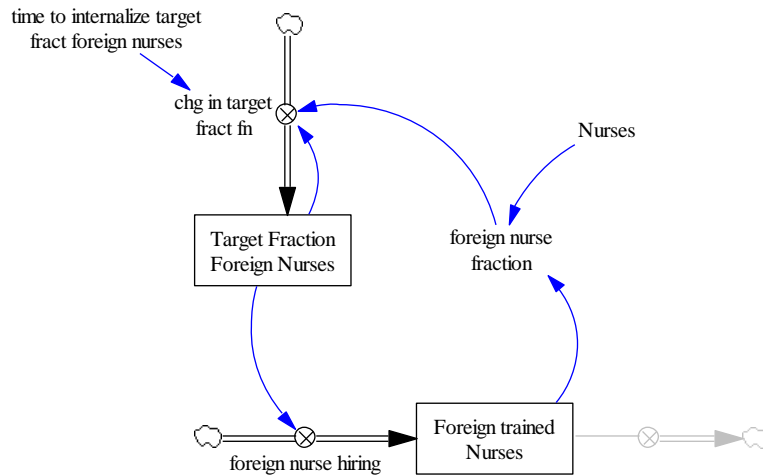
Figure 3 Stock and Flow of Target Fraction Foreign Nurses and Foreign-trained Nurses

Figure 3 illustrates the stock and flow structure of target fraction foreign nurses. This structure represents the adjustment process of the desired fraction of foreign nurses in the system. The desired fraction of foreign nurses changes according to the actual foreign nurse fraction and the time taken to internalize the change. Time to internalize target fraction foreign nurses determines the rate at which the desired fraction is updated. This constitutes a reinforcing loop: as more foreign nurses are hired, a higher target fraction of foreign nurses within the system is used by the policy makers. Thus, the desired number of foreign nurses increases and subsequently leads to higher desired foreign nurse fraction. However, a higher target foreign nurse fraction leads to a smaller pool of desired domestic nurses (Figure 1). Therefore, desired enrollment is reduced.

Discussion

The model starts in steady state equilibrium. It simulates the dynamics of foreign and domestic nurses over a 30-year planning horizon. In equilibrium, the fraction of foreign nurses remains constant at 20%. To examine the causes of the increasing number of foreign nurses, we perturb this equilibrium and trace the impact of that perturbation on the system. Target nurses is set to increase 3% annually from year 5 onwards. As a result, foreign nurse fraction presents an S-shape growth behavior. It increases exponentially from year 5 to 9. After that, it presents a goal-seeking behavior. Eventually, it will level off. The simulated result replicates the reference mode (Figure 4).
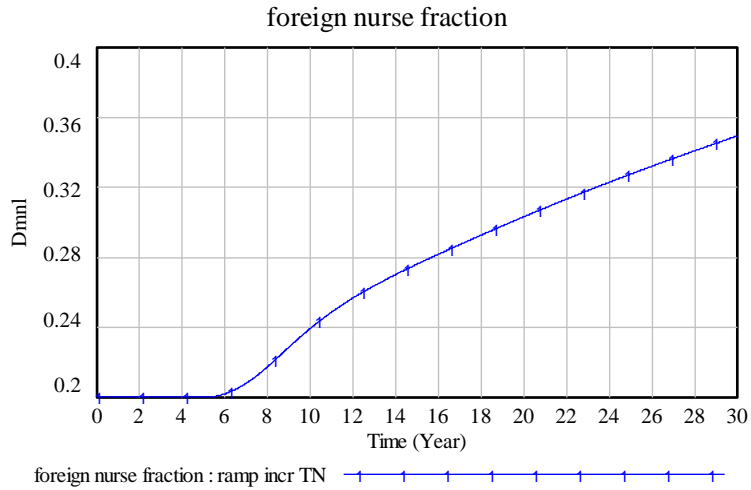
Growing FN Concentration and Its Impact_004

foreign nurse fraction

Figure 4 Reference Mode: Increase in foreign nurse fraction every year

Time to Hire Foreign Nurses and Nurse Adequacy Gap
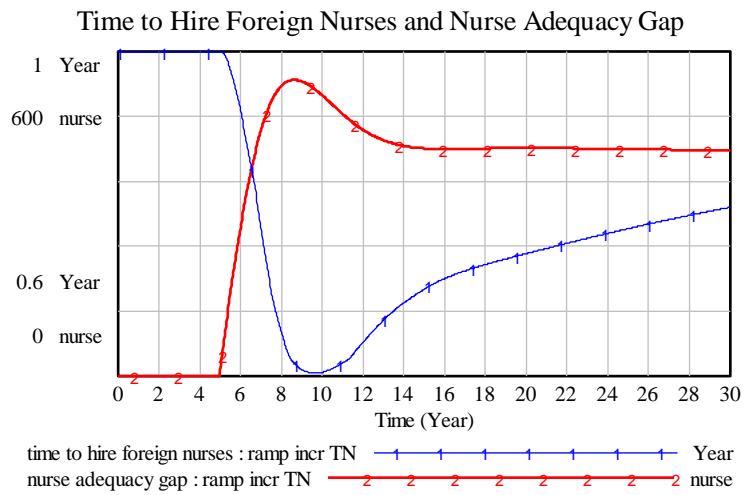
Figure 5 The impact of ramping up *target nurses* on *time to hire foreign nurses* and *nurse adequacy gap*
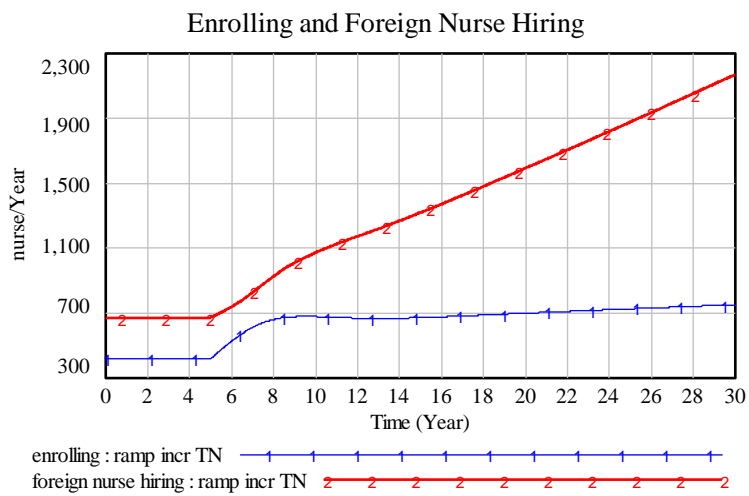
Enrolling and Foreign Nurse Hiring

Figure 6 The impact of ramping up *target nurses* on student enrollment and foreign nurse hiring

In steady state, the desired number of nurses (target nurses) is equal to the sum of domestic nurses and foreign-trained nurses; thus, nurse adequacy gap remains constant at zero. In such a state, school enrollment remains constant and is sufficient to replace domestic nurses who leave the system as well as students who drop out; foreign nurse hiring is equal to foreign nurses who leave the system. When the system is perturbed, the nurse adequacy gap will change. When target nurses is increased every year, components within the system respond to the new goal. Time to hire foreign nurse is reduced resulting in increasing aggressiveness in the hiring process (Figure 5 and B1 in Figure 7) and more foreign nurses are hired to reduce the shortages at a faster rate (Figure 6 and B2 in Figure 7). The increasing foreign nurse fraction leads to a growing desired fraction of foreign nurses (R2 in Figure 7). This reduces the desired number of domestic nurses (R1 in Figure 7). Thereafter, the pressure to increase school enrollment is relieved (B3 in Figure 7). As the shortfall continues, the training capacity rises more slowly than foreign nurse hiring; therefore, the training capacity has less of a contribution to reducing the shortage. Consequently, relatively fewer domestic nurses are educated. This characterizes a goal erosion phenomenon . Traditionally, the system achieves the stated goal, target nurses, by enrolling students and hiring foreign nurses. However, due to the pressure to alleviate nurse shortages, more foreign nurses are hired. As the fraction of foreign nurses grows, more foreign nurses are used as the solution to alleviate nurse shortages. This has become an implicit goal for the system. As a result, fewer students are enrolled and the function of the training capacity deteriorates over time.

In system dynamics terms, loop B3 loses its strength as R1 and R2 reinforce the strength in B2. B2 becomes more dominant in the system and this development shifts the burden from training nurses locally to hiring nurses from external sources.
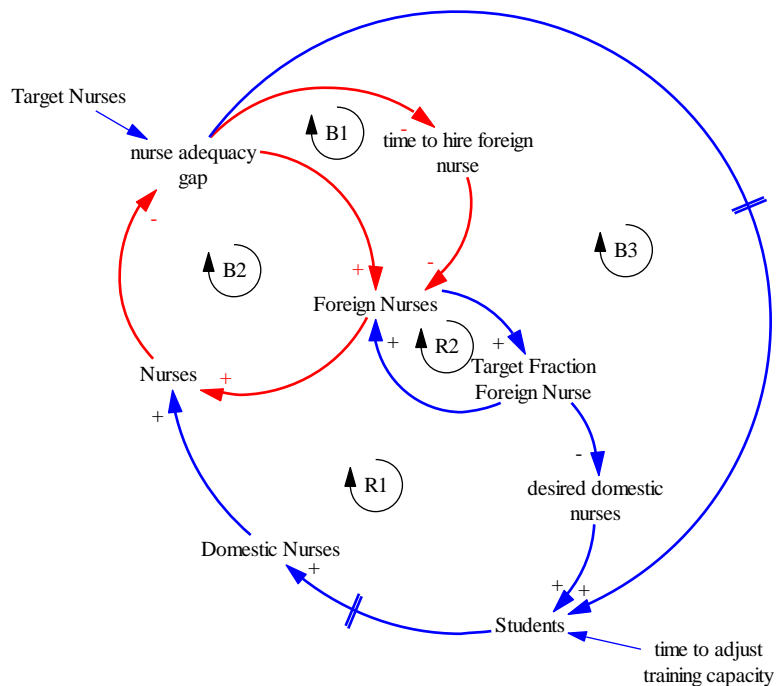

Figure 7 Five feedback loops illustrating the relationship of *nurse adequacy gap*, foreign nurses and domestic nurses

Test 1: step increase demand for nurses

In this test, *Target Nurses* is raised by 10% to 11,000 nurses from year 5 onwards. As the demand is increased, components within the system respond toward the new target. Figure 6 shows that *foreign nurse fraction* peaks at year 7 with 23%; then, it decreases gradually to 22.5% and settles into a higher steady state from year 21 onwards.
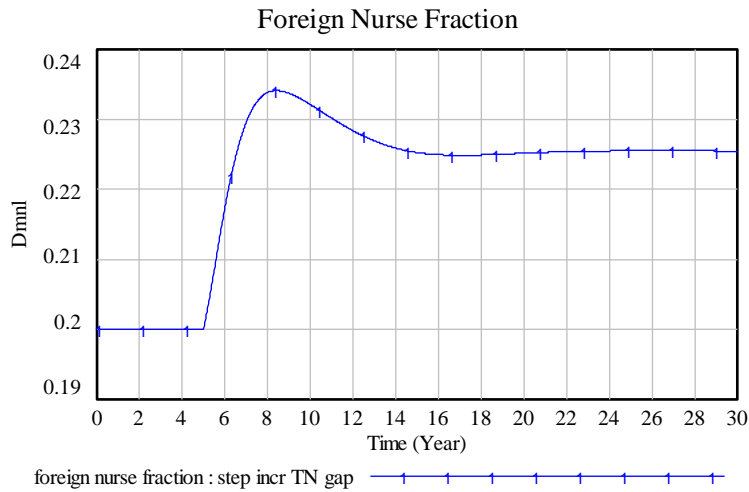

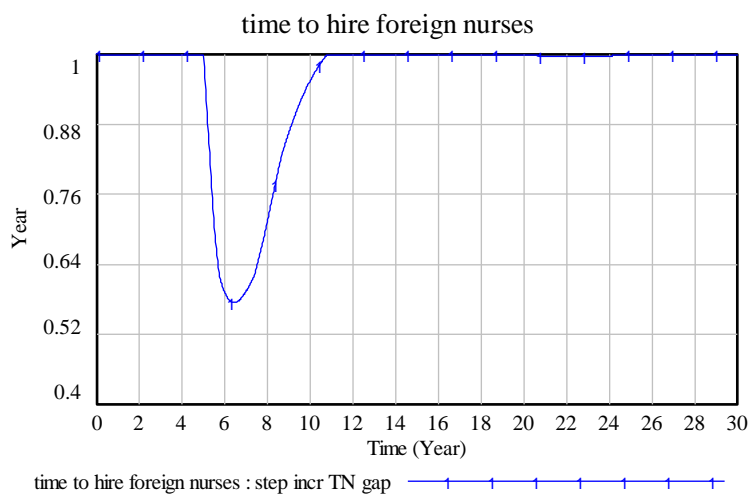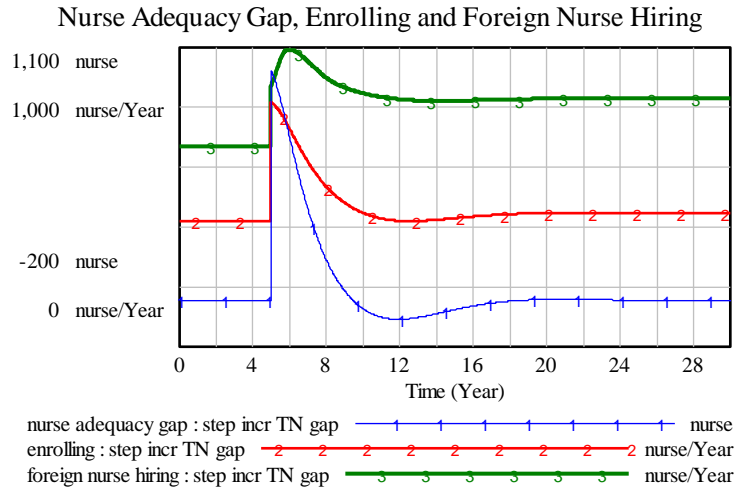**Figure 8 Test 1: The impact of a step increase in *target nurses* on *foreign nurse fraction***

Figure 9 Test 1: The impact of a step increase in *target nurses* on *time to hire foreign nurses*

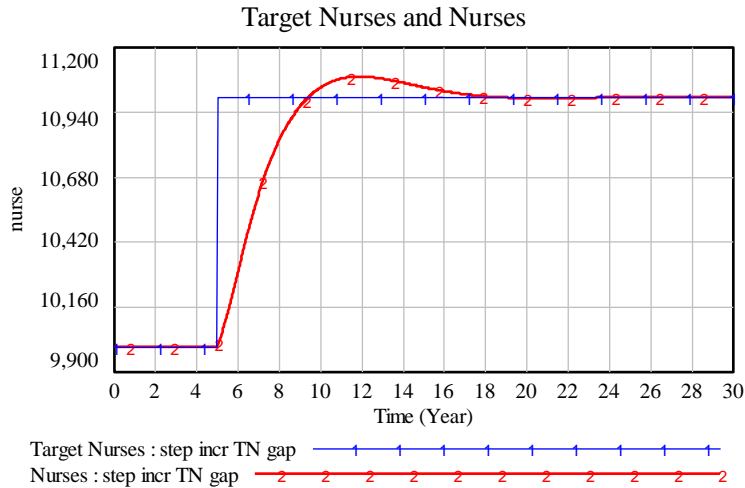Nurse Adequacy Gap, Enrolling and Foreign Nurse Hiring

Figure 10 Test 1: The impact of a step increase in *target nurses* on student enrollment and foreign nurse hiring

With mounting pressure to close the gap as soon as possible, foreign nurse hiring time shortens to 0.6 year at year 6 (Figure 9). The foreign nurse hiring rate increases 49% in response to the 10% increase in target nurses (Figure 10). In comparison, enrolling immediately increases 96%. From this, it would be easy to conclude that the vast burden of response to increased demand falls to the domestic training. However, if we look at the absolute numbers, the increase in foreign nurse hiring is 324 nurses/year compared to 400 for enrolling. That is too say, what is supposed to be 20% of the nurse population is responsible for 45% of the response to changing demand. This apparent discrepancy occurs because the average tenure of foreign nurses is so much shorter. If foreign nurses had the same average tenure as domestic nurses (25 years), their annual turnover would only be 80, for which 324 represents a 400% increase. In this case it would be very clear that the smaller population is responsible for a disproportionately large share in the adjustment, and that a rising fraction of foreign nurses should be expected as a result.

Since it takes 5 years to adjust enrollment and educate domestic nurses, the stock of domestic nurses presents S-shapes growth (Figure 11). It peaks at year 13 with 8560 nurses, 8 years after the spike in enrollment. As the nurse adequacy gap shrinks, enrollment declines. Thus, the stock of domestic nurses continues to grow at a decreasing rate until it slightly overshoots and reaches a new steady state from year 20 onwards.

Growing FN Concentration and Its Impact_004

Target Nurses and Nurses

Figure 11 Test 1: The impact of a step increase in *target nurses* on the stock of nurses

As the stock of nurses reaches the target at year 9, the nurse deficit disappears. Because of the delay involved in training, the total number of nurses overshoots the target between year 9 and 18.

Because of the surplus, both enrolling and foreign nurse hiring are reduced below the respective replacement rates between year 19 and 26. This leads to a repeated deficit in nurses. Thus, enrollment and foreign nurse hiring increase again to reduce nurse shortage. The discrepancy of nurses disappears from year 26 onwards. Then, enrolling and foreign nurses hiring settle into new steady states.

Test 2: increase and decrease time to adjust training capacity

This test compares the impact of lengthening and shortening the time taken to adjust training capacity on the overall nursing capacity. Time to adjust training capacity is shortened and lengthened to 1 year and 5 years respectively. Immediately after the 10% (1000 nurses) increase in target nurses at year 5, enrolling and foreign nurse hiring spike to increase the stock of nurses in order to meet the target. When time to adjust training capacity is shortened, 800 or 192% more students are enrolled (Figure 12); and 200 or 30% more foreign nurses are hired at year 5. The nurse adequacy gap starts to decline after year 5. Therefore, enrolling also decreases. But due to the delay in internalizing the fraction of foreign nurses, foreign nurse hiring only peaks at year 6. The aggressive adjustment in enrolling results in higher graduation rate, with 244 or 76% more graduates at year 7. The nurse deficit is eliminated around year 8. However, the students in the training pipeline continue to graduate and become domestic nurses. This leads to a surplus of 962 nurses at year 11 (Figure 13). Consequently, both enrolling and foreign nurse hiring fall below the replacement rates. At year 15, nurse deficit re-appears. So, enrolling and foreign nurse hiring increase in response to the deficit. Until the stock of nurses meets the new target from year 26 onwards, *enrolling, graduating* and *foreign nurse hiring* settle into new steady states.

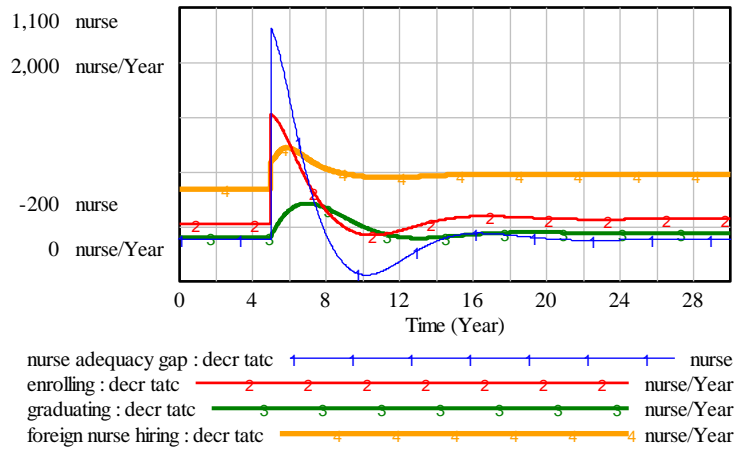## Nurse Adequacy Gap, Enrolling, Graduating and Foreign Nurse Hiring

Figure 12 Test 2: The impact of shortening *time to adjust training capacity* **on** *nurse adequacy gap,* *enrolling, graduating,* **and** *foreign nurse hiring*
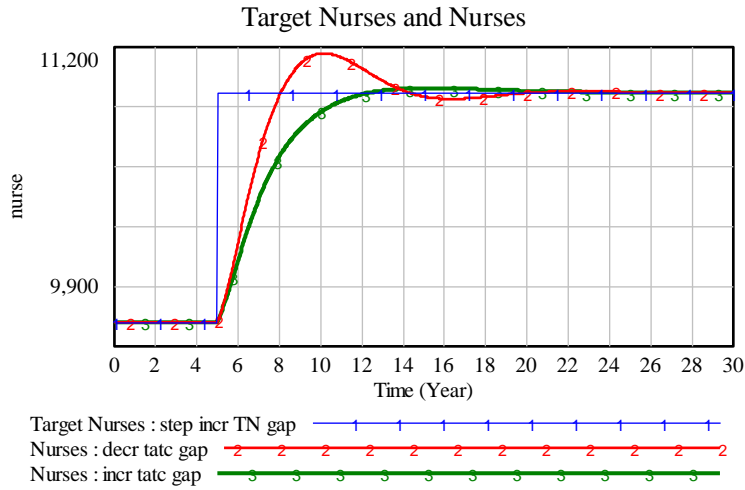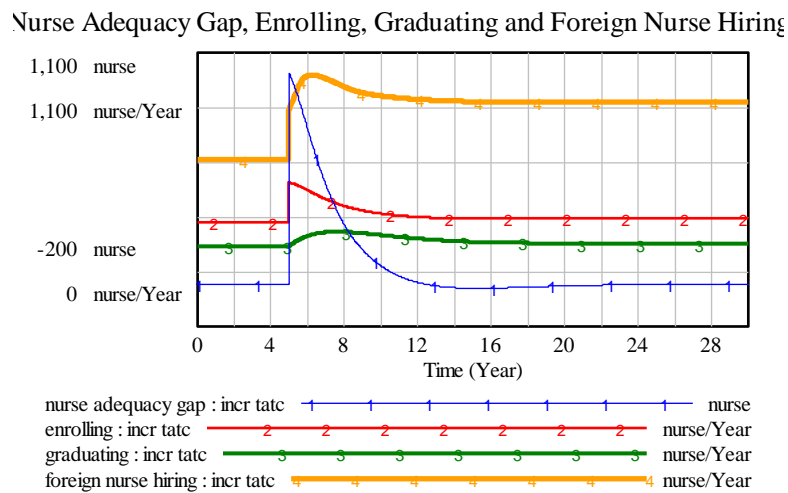
Target Nurses and Nurses

Figure 13 Test 2: The impact of lengthening and shortening *time to adjust training capacity* **on the stock of nurses**

When time to adjust training capacity is lengthened to 5 years, enrolling increases by 160 students or 38% at year 5 (Figure 14); whereas foreign nurse hiring increases by 200 or 30%. Again, due to the delay in internalizing target foreign nurse fraction, foreign nurse hiring rises to 336 at year 6 while nurse adequacy gap starts to decline. *Graduating* increases gradually and peaks at year 8 with 57 or 18% more graduates. Hence, the nurse deficit is eliminated. The lag in adjustment of the training capacity causes the stock of nurses reaching the target at year 13 instead of 8 and it forces the total number of nurses to overshoot the target by about 20 nurses between year 13 and 20. After that, the system settles into a new steady state from year 26 onwards.

Figure 14 Test 2: The impact of lengthening *time to adjust training capacity* on *nurse adequacy gap*, *enrolling*, *graduating*, and *foreign nurse hiring*

Both lengthening and shortening the time to adjust training capacity lead to a new steady state 21 years after the immediate 10% increase in target nurses. However, with more aggressive adjustments to the enrollment, the stock of nurses demonstrates greater volatility; with less aggressive adjustments to the enrollment, the stock of nurses overshoots the target slightly, but will eventually fall on the target and stabilize at the same time.

Test 3: increase and decrease time to hire foreign nurses

The purpose of this test is to examine the effects of shortening and lengthening the time taken to hire foreign nurses. In steady state, time to hire foreign nurses is 1 year. In this test, time to hire foreign nurses is extended to 5 years and reduced to 0.5 year respectively from year 5 onwards. In the first case, foreign nurse fraction increases less than 1% after time to hire foreign nurses is increased (Figure 15). Then, it decreases linearly and levels off at 19% from year 22 onwards. In the second case, foreign nurse fraction increases drastically and peaks at 26% at year 7. Thereafter, it starts decreasing linearly and levels off at 25% from year 19 onwards. Once the system settles into a steady state, foreign nurse fraction is higher with a shorter time to hire foreign nurse.
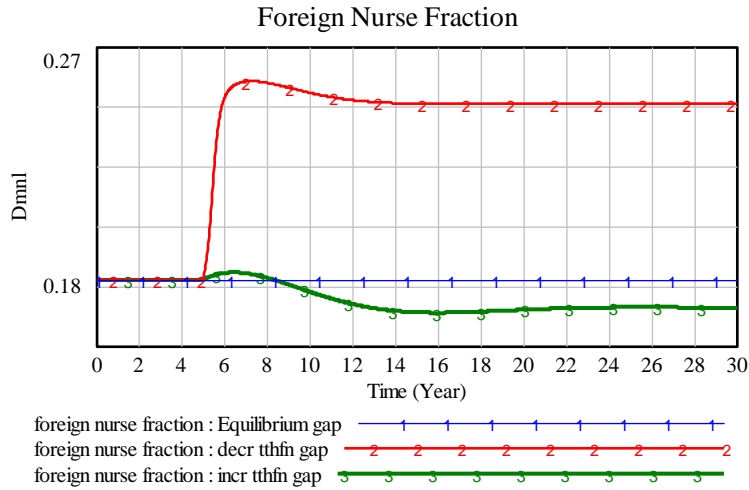
Figure 15 Test 3: The impact of increasing and decreasing time to hire foreign nurses on *foreign nurse fraction*

A longer time in hiring foreign nurses slows down foreign nurse hiring; thus, it takes 3 years longer than in the case with shorter hiring time to eliminate the shortfall in nurses (Figure 16). Because the deficit of nurses persists longer, more students are enrolled between year 8 and 11. The reduction in foreign nurse hiring is offset by a higher enrollment. This test demonstrates that a longer time to hire foreign nurses does not lead to stability in the system. Both the lengthening and shortening of the time to hire foreign nurses lead to the overshoot and undershoot of target nurses. But with a shorter time to hire foreign nurses, the system achieves the target faster.
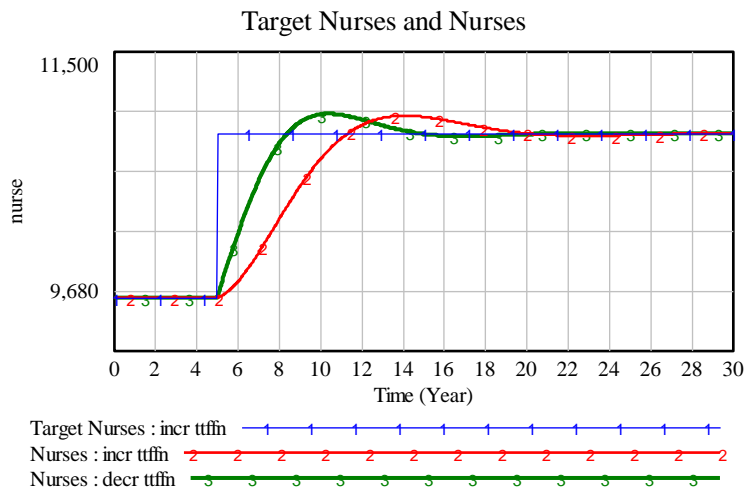

Figure 16 Test 3: The impact of increasing and decreasing time to hire foreign nurses on the stock of nurses

Test 4: keep desired foreign nurse fraction constant

In this test, target nurses is set to increase immediately by 10% from year 5 onwards, while time to internalize target fraction foreign nurses is increased to 99999 years so that the target does not change. Target fraction domestic nurses and target fraction foreign nurses remain at 0.8 and 0.2 respectively throughout the simulation.

Growing FN Concentration and Its Impact_004

This test, in isolation, has almost no impact on system behavior. The foreign nurse fraction again climbs to about 23% then settles down to a new steady state value of 22.5%. While this result seems surprising at first, on reflection it is clear that once the total number of nurses reaches the target there is no mechanism to adjust the relative number of foreign nurses. Both foreign and domestic nurses leaving are being replaced one-for-one.

In order to adjust the fraction of foreign nurses in the absence of an aggregate shortfall or surplus in nurses the number of domestic (or foreign) nurses needs to be targeted directly. If we reformulate the adjustment to desired enrollment as *(*desired domestic nurses - Domestic Nurses) /time to adjust training capacity instead of nurse adequacy gap * target fraction domestic nurses / time to adjust training capacity where desired domestic nurses is computed using target fraction domestic nurses the test does show a significant change.
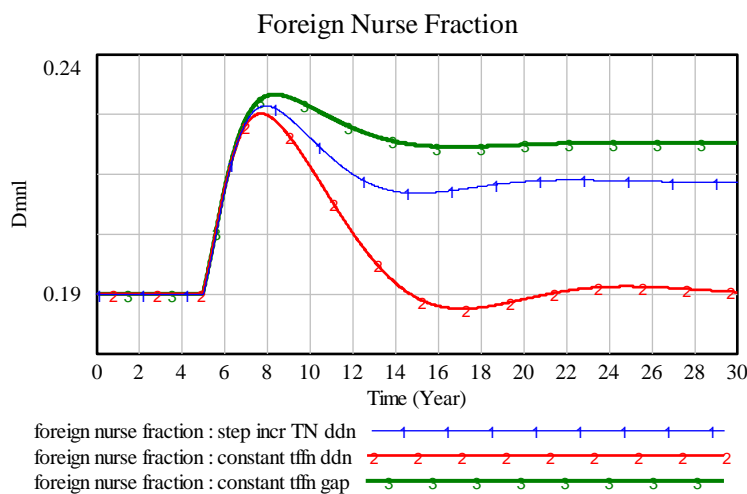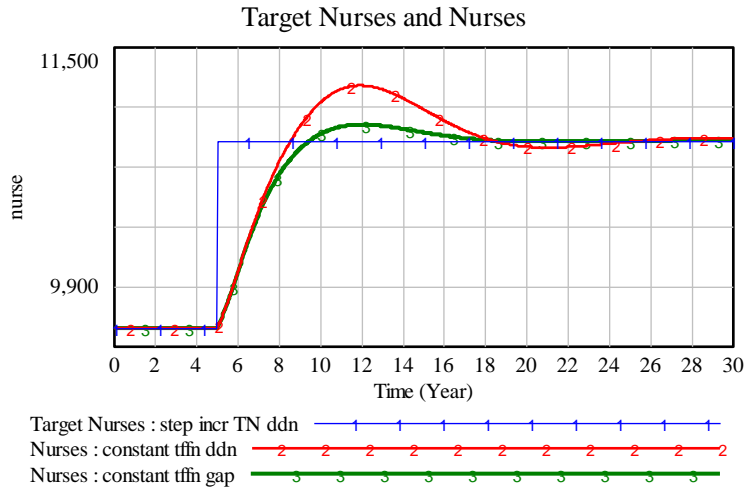

Figure 17 Test 4: The Actual foreign nurse fraction with constant target fraction

Figure 17 shows the foreign nurse fraction from the original formulation, using the modified formulation discussed above and using the modified formulation with the target fraction held constant. In all cases the initial response is the same, but the only with the target held constant does the fraction eventually return back to its original value (after an overshoot). This test shows that with a constant desired fraction of foreign nurses, the burden to train nurses internally is maintained; thus, more domestic nurses are trained. However, a long delay in adjusting and updating the training capacity leads to over- and under-enrollment. As a result, the total number of nurses oscillates around the target (Figure 18).

Figure 18 Test 4: The impact of anchoring Target Foreign Nurse Fraction on the stock of nurses

A final comment on this test is warranted. In performing it we have altered the formulation of the target number of nurses in training to be based on the desired level of domestic nurses instead of the gap in the number of nurses. The same logic could be applied to foreign nurses. The effect of doing so, however, is to greatly diminish the response of foreign nurse hiring to changing demand conditions. This makes the foreign nurse balancing loop extremely weak and the system become both less responsive and less stable. While this definitely helps to prevent drift in the fraction of foreign nurses, the ability to meet nursing needs is severely degraded.

Policy

From the results in the previous section, we learned the following: (1) both adjusting hiring and training based on current shortfalls and a drifting goal will lead to a growing fraction of foreign nurses; (2) increase in time to adjust training capacity stabilizes the stock of nurses; (3) with a constant desired fraction of foreign nurses, the burden of reducing nurse shortage is divided among internal and external sources instead of shifting the burden to the external sources alone. Thus, we incorporate the findings from the test to formulate a policy to stabilize the system and eliminate the nurse deficit quickly without eroding the local training capacity.
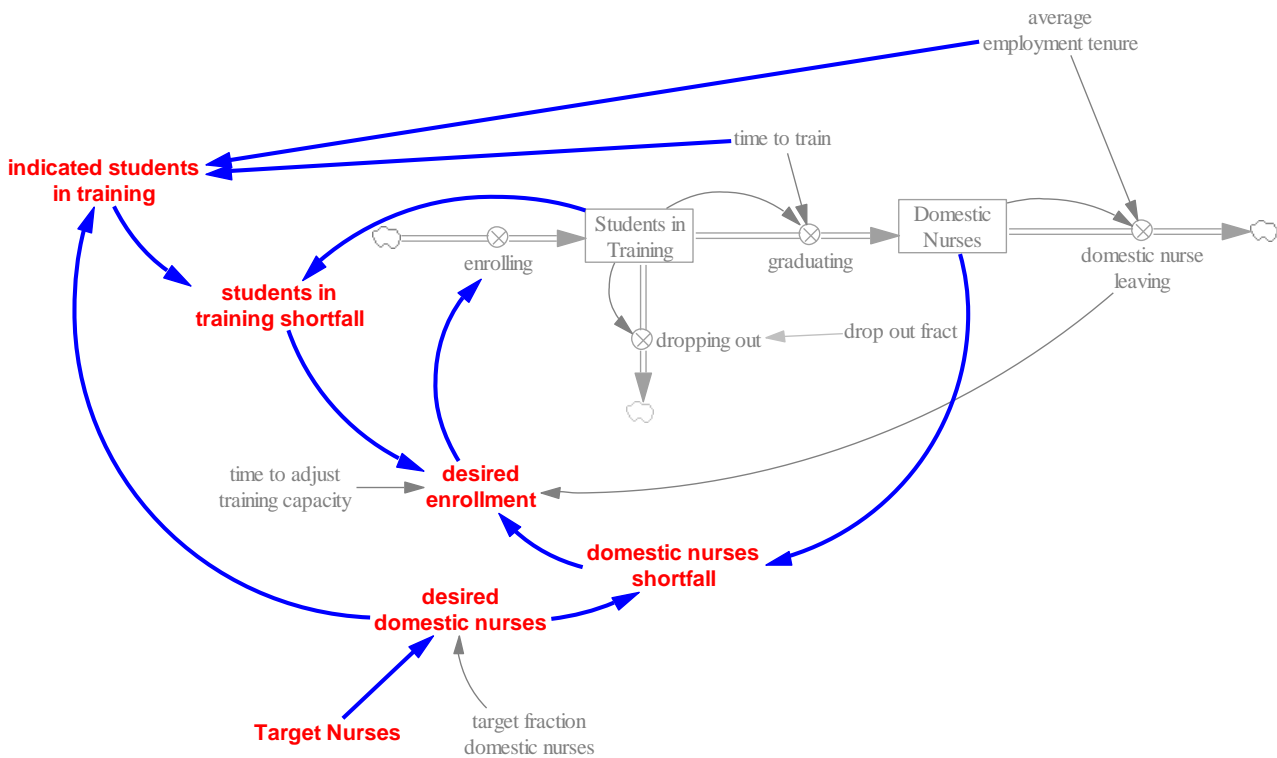
Figure 19 The new policy structure added to the model

In this new policy, the time to internalize target fraction foreign nurse is lengthened to an infinitely large number to keep target fraction foreign nurse unchanged at 0.2. Thus, the desired number of domestic nurses becomes a constant and the feedback from target fraction foreign nurse is eliminated. This prevents the system from seeking a drifting goal. In parallel, the time to reduce foreign nurse hiring is reduced when nurse surplus occurs. The foreign nurse hiring rate changes according to nurse adequacy gap and target fraction foreign nurse; when there is nurse surplus, foreign nurse hiring reduces very quickly. Lastly, the determination of enrollment will include the desired number of domestic nurses, expected leaving rate, dropout rate and shortfall in students in training, which is discrepancy between the indicated number of students in training and the actual state of students in training (Figure 19). Indicated students in training is determined by the number of desired domestic nurses, average residence time of domestic nurses and delay in training. Domestic nurses shortfall is determined by the stock of domestic nurses and the targeted number of domestic nurses in the system instead of nurse deficit. Using the stock value to determine enrollment will reduce variability in enrollment as the nurse deficit varies. The added policy structure keeps the pressure to train on the training capacity while the training capacity seeks to achieve the desired enrollment.

Figure 20 shows that with this new policy, nurses reaches target nurses at year 9. Nurse overshoots the target from year 9 to 26 by about 60 nurses at its highest, which is slightly lower than that in the base case. Nurses reaches the target and remains steady state from year 27 onwards, 23 years after the increase in *target nurses*.

Target Nurses and Nurses
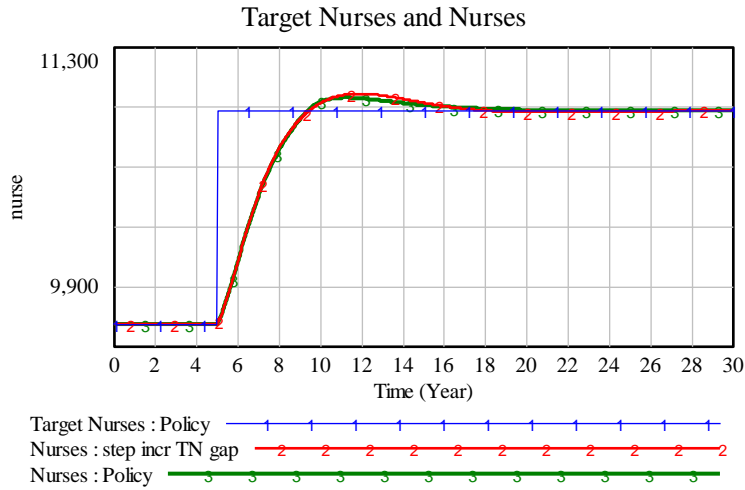
Figure 20 The impact of the new policy with a constant Target Fraction Foreign Nurses and desired enrollment based on Students in Training and Domestic Nurses on the stock of nurses

With the new policy, foreign nurses are hired at a faster rate to fill nurse shortages quickly when nurse adequacy gap is large. These foreign nurses are trained and the delay in the hiring process is shorter than that in training domestic nurses. Thus, foreign nurse fraction surges (Figure 21). When the number of nurses in the system meets the target at year 9, foreign nurse hiring decreases; it decreases at an increasing rate in the presence of nurse surplus between year 9 and 26. From year 29 onwards, foreign nurse fraction falls back on target fraction foreign nurse.

On the other hand, indicated students in training spikes as target nurses increases immediately. This leads to an increase in enrolling. Students in training surges from year 5 and peaks at year 8 with 42% or 400 more students. As nurse deficit shrinks, enrolling decreases at a decreasing rate until all nurse shortages are filled. Until then, students in training reaches a new higher steady state with 1056 students from year 29 onwards. As more students graduate, the stock of domestic nurses accumulates and reaches desired domestic nurses from year 29 onwards (Figure 22). In the base case, the desired enrollment decreases as the nurse shortages are filled by foreign nurses. Thus, the stock of domestic nurses is lower. As a result, the system is occupied by a higher fraction of foreign nurses than that with the new policy.

Target Foreign Nurse Fraction and Foreign Nurse Fraction
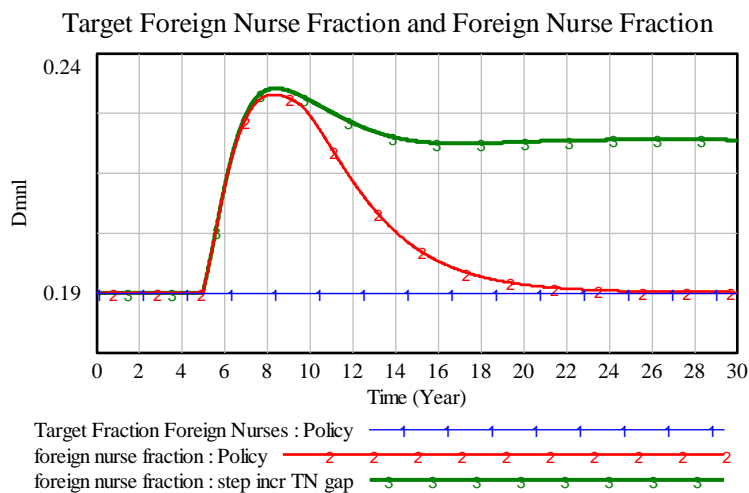
Figure 21 The impact of the new policy with a constant Target Fraction Foreign Nurses and desired enrollment based on Students in Training and Domestic Nurses on foreign nurse fraction

Growing FN Concentration and Its Impact_004

Desired Domestic Nurses and Domestic Nurses
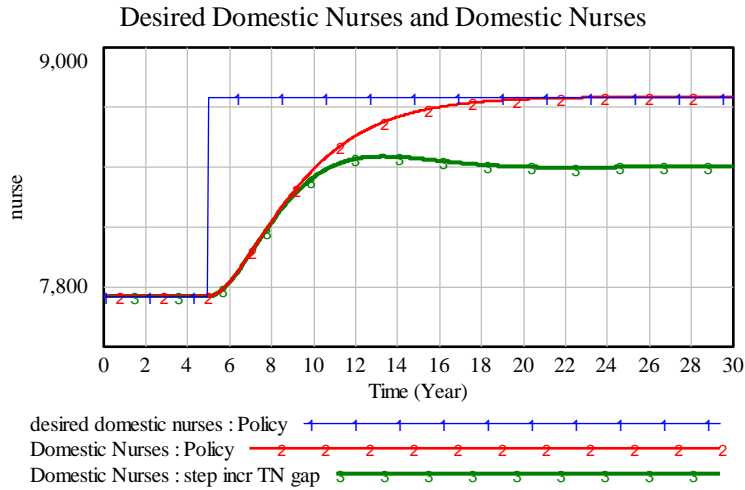
Figure 22 The impact of the new policy with a constant Target Fraction Foreign Nurses and desired enrollment based on Students in Training and Domestic Nurses on the stock of Domestic Nurses

Conclusion

We have demonstrated that the growing fraction of foreign nurses need not be caused by exogenous factors but may be the result of policies embedded in the system. It is the goal of reducing the nurse shortage by hiring more foreign nurses that leads to the increase in foreign nurse fraction. As an unintended consequence, the local training capacity deteriorates, or at least does not grow sufficiently, over time. To tackle the goal erosion phenomenon, the desired fraction of foreign nurses should be fixed. In addition, the determination of enrollment should take the stock values of students and domestic nurses, average residence time of domestic nurses, and delay in training into consideration. Hence, the pressure to eradicate nurse shortage will be directed to the local training capacity. This policy results in stable adjustment to the targets, though that adjustment does take a surprisingly long time.

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Growing FN Concentration and Its Impact_004