

```

% Function to calculate the Hessian of R0 to the s by 1 parameter vector
% theta where there is only one kind of offspring (stage 1).
%
% Input:
%   U = the transition matrix (n by n matrix)
%   F = the fertility matrix (n by n matrix)
%   s = length of parameter vector theta
%   DUt = D[vecU, theta] (n^2 by s matrix)
%   DFt = D[vecF, theta] (n^2 by s matrix)
%   HUt = H[vecU, theta] (n^2*s by s matrix)
%   HFt = H[vecF, theta] (n^2*s by s matrix)
%
% Function outputs result of Equation (46) (s by s matrix).
%

```

```
function H = HR0_theta_1(U, F, DUt, DFt, HUt, HFt)
```

```
A = U + F;
```

```
[n2,s] = size(DUt);
```

```
[n, n] = size(A);
```

```
In = eye(n);
```

```
In2 = eye(n^2);
```

```
Is = eye(s);
```

```
Ins = eye(n*s);
```

```
e1 = zeros(n,1);
```

```
e1(1) = 1;
```

```
F = A-U;
```

```
N = inv(In - U);
```

```
R = F*N;
```

```
Rt = R';
```

```
DRt = kron(N', In)*DFt + kron(N', R)*DUt; % Eq (C-27)
```

```
DNt = kron(N', N)*DUt; % Eq (C-33)
```

```
Dvec1 = kron(kron(In,Kmn(n,n)),In) * kron(In2, In(:))*DNt; % Eq (C-31)
```

```
Dvec2 = kron(kron(In,Kmn(n,n)),In) * ( kron(In2, Rt(:))*DNt + kron(N(:, In2)*Kmn(n,n)*DRt ); % Eq (C-32)
```

```
HRt = kron(N', Ins)*HFt + kron(In2, DFt)*Dvec1 + kron(kron(N',R),Is)*HUt + kron(In2, DUt)*Dvec2; % Eq (C-30)
```

```
H = kron(kron(e1', e1'),Is) * HRt; % Eq (46)
```

```
end
```